First Report to the Water Research Committee of the Royal Society, on the present State of our Knowledge concerning the Bacteriology of Water, with especial reference to the Vitality of Pathogenic Schizomycetes in Water.

By Percy F. Frankland, Ph.D., B.Sc. (Lond.), F.R.S., Professor of Chemistry in University College, Dundee, and Marshall Ward, Sc.D., F.R.S., F.L.S., Professor of Botany in the Royal Indian Engineering College, Coopers Hill. Presented to the President and Council, May 19, 1892.

Introduction.

The interest attaching to the presence of micro-organisms in water originated principally in the proof, which has been furnished by medical men, that some zymotic diseases are communicated through drinking water. In the case of two diseases, at any rate, the evidence may be regarded as conclusive on the main point, and the communicability of Asiatic cholera and typhoid fever forms one of the cardinal principles of modern sanitary science, which year by year is becoming more widely recognised and generally accepted. The germ theory of zymotic disease, which has become more and more firmly established during each successive decade of the past half century, was naturally soon impressed into the service of those who sought to explain the empirical fact that these particular diseases are frequently communicated by water. It is significant that these views concerning the propagation of cholera and typhoid, and the importance to be, therefore, attached to drinking water in connexion with public health, are mainly English in origin, and were for many years unflinchingly preached and practised by English sanitary authorities, at a time when the germ theory of disease was a speculation, and not established as it now is. It is only necessary to read, by the light of our knowledge of to-day, the Sixth Report of the Rivers-Pollution Commissioners (1868), written more than eighteen years ago, to be convinced of the intuitive sagacity and acumen which has been displayed in this country in matters of sanitation.

The germ theory of disease having thus so early become interwoven with the consideration of potable waters, it is easy to understand with what eager interest the vigorous development in our knowledge of micro-organisms in general, and of their connexion with

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disease in particular, which has taken place within the past fifteen years, has been watched by those who have had to devote much attention to the sanitary aspects of water-supply.

The subject of our particular enquiry is, therefore, a modern one, and may be regarded as having been made amenable to successful treatment by the introduction of Koch's method of gelatine-plate cultures in 1881, and subsequent improvements on the same.*

The publication by Koch of his beautiful and comparatively simple methods of bacteriological study gave an impulse to this kind of work throughout the civilised world. These methods, in spite of certain imperfections from which they never professed to be free, at once opened up the possibility of solving a number of problems connected with water-supply which had long been matters of dispute and speculation amongst hygienic authorities.

As is now well known, Koch's method of gelatine-plate culture admits of an estimate being made of the number of living germs present in a given quantity of any material. That this estimate is a very rough one, and that there are a number of different kinds of germs which it is incapable of revealing, was also known, and has been more or less admitted from the outset. Now this possibility of estimating the number of microbes in a given volume of water has been largely made use of by numerous investigators for a number of different purposes.

In the first instance, this method has been extensively employed both in this country and abroad for determining the relative richness in micro-organisms (capable of developing in gelatine) of various natural waters. On the Continent, and more especially in Germany, it was assumed that the relative numbers of microbes present in different waters afforded evidence of the extent to which they had been contaminated, and there were not wanting those who hastily set up arbitrary standards of purity based upon a most limited experience of the number of micro-organisms revealed by the gelatine test. By those who were simultaneously employing the method in this country more caution and reserve were exercised in this respect, the results being tentatively chronicled without comment or deduction as to purity.

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* Koch's first announcement of his new method was made at the meeting of the International Medical Congress in London, in August, 1881 (see 'Quart. Journ. Microsc. Sc.,' Oct., 1881, p. 650), and then published in the 'Mitth. aus d. K. Gesundheitsamte,' vol. 1, 1881 (see also 'Berl. Klin. Wochenschr.,' 1882, No. 5). It should be noted, however, that Koch's gelatine-plate method was an improved adaptation of one introduced long before by the botanists Brefeld and Klebs (see Brefeld, "Methoden zur Unters. der Pilze," 'Abh. der Phys.-Med. Gesellsch. in Würzburg,' 1874; also 'Landwirthsch. Jahrb.,' vol. 4, H. 1, and 'Unters. über Schimmelpilze,' 1881, H. 4; also Klebs, "Beitr. zur Kenntn. d. Mikrokokken," 'Arch. für exp. Pathol.,' vol. 1, 1873, and De Bary, 'Lectures on Bacteria,' Engl. ed., 1887, p. 35). A fair view of the matter is given by Hueppe, 'Die Methoden der Bakterien-Forschung,' 1885, p. 103. To Koch belongs the credit of having applied these plates to the purpose of separating the various colonies of mixtures of micro-organisms.

The prudence of this caution was soon apparent, when both in England and in Germany it was discovered in 1885 that many forms of micro-organisms could multiply to an astonishing extent in waters of great organic purity, including distilled water itself. It is obvious that this discovery at once subverted the artificial standards which had been proposed, for, although a small number of micro-organisms might frequently point to little or no contamination having taken place, a large number could only under special circumstances be viewed as conclusive evidence of proportionate contamination.

Another question was, however, being simultaneously attacked, both in this country and on the Continent, viz., the effect of various processes of purification on the bacterial life present in water. This question, which is of evident importance, could be investigated with considerable precision by means of the gelatine-plate method, in spite of its imperfections, for by applying the same mode of culture to a particular water before and after purification, it is obvious that the defects neutralise each other, and that a true differential result can be obtained. In this manner, the value of a number of filtering materials has been ascertained, and the remarkable efficiency of water-works sand-filtration for the first time established. Again, the fact that practically all surface waters exhibit a large number of microbes by the gelatine test, whilst deep well and spring waters yield very few, or in some cases none, shows how perfect, as regards removal of micro-organisms, must be the natural filtration which water undergoes in traversing great depths of porous strata in the earth.

It has also been shown that in the subsidence of solid particles often a surprisingly large proportion of the micro-organisms present in water are carried to the bottom, a matter which is of particular interest and importance in connexion with the natural purification of surface waters in rivers, lakes, and storage reservoirs, as well as in the artificial treatment of water-supplies by Clark's softening process, and other methods of precipitation. In applying the gelatine test to these various purification processes it is, however, essential, if an accurate result is to be obtained, that the water should be examined *immediately* (within a few hours) after the purification is completed, and before the number of microbes in the purified water can have multiplied naturally.

Another use to which the bacteriological methods have been applied is to the actual discovery of pathogenic microbes in water, and, in the opinion of some, this should indeed be the primary object of bacteriology in connexion with water-supply. This view appears to us, however, too narrow, as waters are surely to be condemned for drinking purposes not only when they contain the germs of zymotic disease at the time of analysis, but in all cases when they are subject to contaminations which, like sewage, may at any time convey such germs.

Notwithstanding that great difficulties usually invest the discovery of particular pathogenic forms in the presence of large numbers of ordinary water microbes, the spirillum of Asiatic cholera was early discovered in water by Koch, whilst the bacillus of typhoid fever has more recently been on several occasions detected by various investigators in drinking waters which had been suspected of communicating this disease. It is obvious that such discoveries are rather of interest on account of their confirming the belief in the communicability of these diseases through water than of special hygienic importance in preventing outbreaks of zymotic disease.

The bacteriological methods of examination have been also employed for a purpose of far greater importance than the mere quest for pathogenic forms in particular water-supplies, viz., for direct experiments on the vitality of known pathogenic organisms in waters of different composition and under varied conditions of temperature and the like. This investigation was also begun independently and almost simultaneously both in this country and on the Continent, and although the question appears at first sight a very simple one, it is in reality surrounded with numerous pitfalls, which have, in some cases, led to very discordant results. Perhaps the greatest difficulty which attaches to this investigation consists in the very different degrees of vitality which are exhibited by one and the same organism at different periods of its life, and according to the previous treatment which the individual and its ancestors have received. On this account a number of individuals of a particular species, on being introduced into a given water, may conduct themselves quite differently from a number of individuals of the same species, but taken from a different source and having another ancestral history. This importance of individuality and pedigree, with which we are so familiar in dealing with the higher plants and animals, must also invariably be taken into consideration in connexion with these lowly forms of life.*

In spite of some conflicting results which have thus not unnaturally been obtained in these investigations, it is sufficiently evident that some pathogenic species, and notably those which form spores, are capable of retaining their vitality in ordinary potable waters for a long period of time, in some cases several months, whilst other forms, especially in the absence of spores, are very rapidly destroyed. In some instances actual multiplication, although but rarely on any very extensive scale, has been observed in the case of some pathogenic forms in potable water, and more frequently in badly contaminated waters and in sewage. In those cases in which pathogenic forms have been introduced into waters in their natural condition, the destruction of these forms has almost invariably been more rapid, and in some cases very much more rapid, than when the same forms were introduced into the same waters after the latter had been previously sterilised. This more rapid disappearance of the pathogenic forms in the unsterilised water is generally accounted for by assuming that they have perished in the struggle for existence with the other microbes present in the water, and which by their nature and previous history are more fitted for this aquatic existence. We are of opinion that these results with unsterilised water must be accepted with considerable caution, as the experimental difficulties involved are very great indeed, and the possibility of the comparatively few pathogenic forms being undiscovered amidst the countless swarms of water organisms must be borne in mind.

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* Particular cases of the application of these methods to the examination of food substances, brewing and distilling waters, the materials of clothing, dyeing and other industries lie beyond our present enquiry; their importance is obvious, as is also the utility of the methods for the analyses of air, soils, &c.

Having thus given a general survey of the present position of our knowledge concerning the bacteriology of water, we shall now proceed to enter into each of the questions involved in more detail, giving special attention to the existing literature on the several parts of our subject.

In view of the fact that the introduction of Koch's methods, in 1881, thus revolutionised the subject of hygiene, we naturally commence our review of the literature at the period just previous to and after the above date. There are, in fact, practically no investigations on the more special part of our subject anterior to this date.

Most of the more systematic work has been done on the Continent, and, at first, especially in the public laboratories of Germany, where the new methods were at once applied industriously to the examination of the bacteria in the air, the soil, food stuffs, water, &c.

A number of French enquirers also arose, though it is significant that Koch's gelatine-plate method to this day has not found much favour in one of the oldest and best of the French stations, the Observatoire de Montsouris, whence excellent work has come.* England, Italy, America, and other countries soon followed; but, although a number of exceedingly valuable memoirs on special questions relating to the general subject were published at an early date in this country and in France, it is still noticeable that most of the prolonged and systematic investigations of the bacterial life to be found in the waters of towns, &c., and statistical comparisons of their behaviour at different seasons, their vitality when placed in special waters, and so on, have come from Germany. Of late years it would be difficult to say where most activity has been displayed, the establishment of the Pasteur Institute in Paris having led to the inauguration of brilliant and industrious researches into every aspect of the questions we are concerned with. Even now, however, it is especially to the reports of the public hygienic institutions of Germany that we must turn for the more technical and systematic comparative researches into the main question of our enquiry—the length of life enjoyed by specific Schizomycetes when placed in arbitrarily selected waters.

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* See 'Annuaire de l'Observatoire de Montsouris,' 1877 to 1891, and Miquel, 'Manuel Pratique d'Analyse Bactériologique des Eaux,' Paris, 1891.

We propose to adopt the following plan of treatment in this Report:—

(1.) To give some account of what species or forms are actually known to occur in natural waters, of various kinds, whether as more or less normal and constant inhabitants of such waters, or as casual foreign intruders. Some of these are well known, others we know very little about, while yet others require careful examination before we can accept them as autonomous. We also refer to a few remarkable forms found in special kinds of water, or under peculiar conditions, only.

(2.) We propose to draw attention to some of the facts now acquired, which throw light on the questions of the relations subsisting between the bacterial contents of natural waters, such as those of rivers, springs, wells, reservoirs, &c., and the air and soil of the neighbourhood, because some of these facts are of great importance as regards the presence and supply of pathogenic germs in such waters. This leads naturally to the discussion of recent experimental investigations into the effects of certain factors of the physical environment, *e.g.*, temperature, light, oxygen, &c., in modifying the life-actions of such bacteria as we are concerned with, and so far as such effects may be expected to affect the general problems at issue.

(3.) The questions, What bacteria can live in such waters as we refer to? Can they multiply and spread in them? Can definitely chosen pathogenic species live and multiply in selected waters; and, if so, how long can they maintain themselves? These, and similar questions relating to them, will be treated in detail as fully as the literature and our own personal experience in these matters enable us to do.

This will, we think, cover the ground of the history and literature of the subject, and will clear the way for our proposals as to lines of enquiry to be entered into forthwith, and as to the methods we intend to put in practice in pursuing the question further.

§ I. *Schizomycetes actually Detected in Natural Waters.*

It has long been known that natural waters, of rivers, springs, ditches, wells, lakes, &c., contain bacteria, often in enormous quantities; and prolonged experience has shown that no kind of ordinary water, whether running or standing, is entirely devoid of these organisms;† though the rule is that the waters of rivers usually contain many more organisms than those of lakes or large reservoirs. Mountain streams are generally less rich in bacterial life, while stagnant or slowly moving waters usually contain many and often peculiar species.

Some of the best studied and longest known aquatic species are the following:—*Cladothrix dichotoma* (Cohn), *Crenothrix Kühniana* (Rabenh.), *Sphærotilus natans* (Kütz.), *Beggiatoa alba* (Vauch.), *Spirillum plicatile* (Ehrenb.), *Bacillus erythrosporus* (Cohn), *Bacterium janthinum* (Zopf), *Bacterium merismopedioides* (Zopf). There are, however, many other forms known to occur in water: *e.g.*, *Sarcina Reitenbachii* (Caspary), *S. hyalina* (Kütz.), *Spirillum serpens** (Müller), *S. tenue** (Ehrenb.), *S. undula** (Müller), *S. volutans** (Ehrenb.), *Monas vinosa** (Ehrenb.), *M. Okenii** (Ehrenb.), *M. gracilis* (Warm.), *Rhabdomonas rosea** (Cohn), *Myconostoc gregarium* (Cohn), *Spiromonas Cohnii* (Warm.), *Micrococcus crepusculum** (Ehrenb.), *M. griseus* (Warm.), *Clathrocystis roseo-persicina* (Kütz.), *Bacterium Termo** (Dujard.), *B. lineola* (Müller), *Bacillus tremulus* (Koch), *B. Ulna** (Cohn), *B. virens* (Van Tiegh.), and many others.‡

With regard to this last list, two remarks are necessary. In the first place, most of the species or forms named are characteristic of waters containing much vegetable or animal matter in a state of decay, whence they are commoner in marshes, ditches, ponds, &c., than in running streams, rivers, and wells; and, in the second, some of the so-called species are certainly not good ones, but what are usually termed "form-species," requiring further examination, and especially by means of continuous cultures. The latter applies particularly to the forms marked * in the above list; we do not accept all the others as satisfactory species, but it is difficult to say anything definite about them. One form (*Clathrocystis roseo-persicina*) has been shown by Lankester§ and Zopf‖ to be very polymorphic, and it

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[†] 'Cohn, 'Beiträge zur Biologie der Pflanzen,' from 1870; as well as in numerous reports concerning drainage from sugar factories, Magdeburg, 1886; Hirt, 'Zeitschr. f. Biologie,' 1879, vol. 15, p. 91; Eyferth, 'Die Mikroskopischen Süsswasserbewohner,' 1877; Kirchner and Blochmann, 'Die Mikroskopische Pflanzen- und Thierwelt des Süsswassers,' 1886; Hulwa, 'Biedermann's Centralbl. f. Agrikulturchemie,' 13, Pt I.

[‡] See Appendix A for literature.

[§] Who named it *Bacterium rubescens.*

[‖] Who terms it *Beggiatoa roseo-persicina.*

is at least not impossible that the forms described as *Bacterium sulphuratum*, *Merismopedia littoralis*, *M. Reitenbachii*, *Monas vinosa*, *M. Warmingii*, *M. erubescens*, *M. Okenii*, *M. gracilis*, *Spirillum violaceum*, *Rhabdomonas rosea*, &c., by different observers are merely form-phases of Lankester's species.* So long as investigators are content with recording and naming forms without cultivating them, such difficulties as the above will increase, and most of the trouble met with in the literature of bacteriology—so far as their morphology is concerned—is traceable to this error.

A still longer list of bacteria are recorded as having been occasionally met with in various waters, though most of them are not characteristic of such habitats. Among these are: *Bacillus subtilis* (Ehrenb.), *Proteus vulgaris* (Hauser), *Bacillus anthracis* (Cohn), *Spirillum choleræ-asiaticæ* (Koch), *Bacillus typhosus* (Eberth-Gaffky), *B. aquatilis sulcatus* (Weichselbaum), *B. dysentericus* (Aradas), *B. thermophilus* (Miqu.), *Micrococcus agilis* (Ali-Cohen), and others.†

Here, again, it must be remarked that many of the forms are unsatisfactory as regards their autonomy—*e.g.*, *Proteus vulgaris*, *Micrococcus agilis*—and that we find no record of the authority for *B. dysentericus*, referred to by Aradas.

We have decided to omit detailed references to numerous other forms, recorded as occurring in water, but under names which convey no specific meaning, though some of them are not necessarily bad records; others, again, are referred to by the authors in such a loose way that it is impossible to accept them until they have undergone revision. Thus, Eisenberg refers to rodlets which he dubs "*Violetter-bacillus*," "*Gasbildender-bacillus*," "*Verflüssigender-bacillus*," &c.,‡ and Perdrix, in an excellent paper§ in other respects, speaks of *Bacille amylozyme*, a form met with in the rivers of Paris. So far as it has been possible we have given these in the lists in Appendix B; but we desire to point out that the labour of hunting up the synonyms recorded for these and other imperfectly named forms is very great, and that, therefore, omissions may possibly be discovered with regard to some of them.

Among such forms we may also mention *Bacillus arborescens*, *B. liquidus*, *B. vermicularis*, *B. nubilus*, *B. ramosus*, *B. aurantiacus*, *B. viscosus*, described by one of us;‖ also Meade Bolton's *Micrococcus*

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* Winogradsky denies the accuracy of Zopf's views on this matter, however (see 'Beiträge z. Morph. u. Phys. der Bakt.,' 1888).

† See Appendix B for a complete list of these and all other bacteria known to occur in various waters.

‡ 'Bakteriologische Diagnostik,' Berlin, 1886. Some of these forms have since received definite names, adopted by Eisenberg in the edition of 1891. (See Appendix B.)

§ 'Ann. de l'Inst. Pasteur.' vol. 5, 1891, pp. 286—311.

‖ Grace C. and Percy F. Frankland, 'Zeitschr. f. Hygiene,' vol. 6, 1889, p. 373.

aquatilis;* the *Vibrio saprophiles*, *V. aureus*, *V. flavus*, and *V. flavescens* of Weibel,† the series of nine micrococci and bacilli isolated by Adametz‡ from certain drinking waters, and a number of forms referred to by Bokorny,§ Rintaro Mori,|| Allen-Smith,¶ Macé,** and several other workers during the last ten years.††

Enough has been said to give point to the statement that Schizomycetes of various kinds are common in ordinary waters. Some of the forms referred to are almost universally distributed, at least in Europe and America.‡‡ Others are mostly confined to foul or contaminated waters, containing decaying animal and vegetable matter,§§ &c., such as pools on moorlands, dirty ditches and canals, docks, &c.

There remains, however, a very large amount of work still to be done in connecting particular forms with particular kinds of water and with particular sources of contamination, which would enormously extend the scope and enhance the value of the bacteriological examination of water from a sanitary point of view.

Other forms, again, are not known to be characteristic of any particular class of waters, but have occurred at intervals in any|||| of them, suggesting that they have gained access as casual intruders. At the same time it may be noted that the systematic determination of forms in natural waters has not yet been sufficiently extensive to warrant definite and positive statements as to the habitats of the species. A shorter list, but one that is growing longer every year, includes forms which are not typically characteristic of waters at all, but are pathogenic species, which have almost certainly been introduced into the waters with foreign matters.¶¶

We have so far confined our attention to waters which are at least sometimes employed for household purposes, and are generally known as "fresh" waters, though they differ enormously in detail if we contrast those of dirty rivers with those of clear streams, or those of open moorlands and marshes with those of wells and springs, and so forth.

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* 'Zeitschr. f. Hyg.,' vol. 1, 1886, pp. 76—114.

† 'Centralbl. f. Bakteriol.,' vol. 4, 1888, p. 225.

‡ 'Mitth. der Oesterr. Versuchsst. f. Brauerei u. Malzerei in Wien,' 1888, H. 1.

§ 'Arch. f. Hyg.,' vol. 8, 1888, p. 105.

|| 'Zeitschr. f. Hyg.,' vol. 4, 1888, pp. 47—54.

¶ 'Medical News,' 1887, p. 758.

** 'Annuaire d'Hyg. et de Méd. Légale,' vol. 17, 1887, No. 4.

†† See Appendix A for further literature.

‡‡ *E.g.*, *Cladothrix dichotoma*, *Crenothrix Kühniana*, *Beggiatoa alba*, &c.

§§ *E.g.*, *Clathrocystis roseo-persicina*, *Sphærotilus natans*, *Bacterium janthinum*, *B. merismopedioides*, &c.

|||| *E.g.*, *Bacillus erythrosporus*, *B. subtilis*, *Micrococcus agilis*, &c.

¶¶ *E.g.*, *Bacillus anthracis*, *B. typhosus*, *Spirillum choleræ asiaticæ*, and others which give rise to disease.

But there are micro-organisms in other classes of waters, not usually employed for domestic purposes on a large scale, *e.g.*, the sea, salt marshes and springs, sulphur springs, and mineral waters of various kinds. As a rule, the bacteria of such waters are different from the above, and often appear to be more restricted in species. Thus:—

In the sea are found *Sarcina litoralis* (Oerst.); *Bacterium fusiforme* (Warm.); *B. Pflügeri* (Ludw.); *Beggiatoa mirabilis* (Cohn); *Phragmidothrix multiseptata* (Engler); *Bacterium litoreum* (Warm.); *Beggiatoa pellucida* (Cohn); *Spirochæte gigantea* (Warm.); *Spirillum volutans** (Warm.); *S. sanguineum** (Ehrenb.); *S. violaceum** (Warm.); *Monas Mülleri** (Warm.), and some others. Here, again, an enormous field exists for further research.

Spirillum Rosenbergii (Warm.) and *S. attenuatum* (Warm.), and some other imperfectly studied forms, affect brackish waters; while *Crenothrix polyspora*, *Cladothrix dichotoma*, and *Leptothrix ochracea* (Kütz.) are described as especially occurring in stagnant waters rich in iron,† and certain other species are found in sulphur springs, and even secrete sulphur in their cells:—*e.g.*, *Beggiatoa alba*, *Monas Okenii*, *Clathrocystis roseo-persicina*, *Sarcina sulphurata* (Winogr.), *Monas vinosa*, and a series of other forms.‡

Others, again, are met with in warm springs, *e.g.*, *Sphærotilus thermalis* (Kütz.), and *Sph. lacteus* (Kütz.), *Detoniella lutea* (Kütz.), *Beggiatoa arachnoidea* (Ag.), *B. alba* (Vauch.), and others.

Many of the foregoing species, and others referred to in Appendix B, p. 244, may be regarded as water-bacteria, *i.e.*, as forms more or less habituated to life in natural waters; but, as already stated, some must be looked upon as occasional intruders, introduced temporarily with foreign matters.

Owing to the importance of some of these forms in causing diseases in man and other animals, it is necessary to look with grave suspicion on waters that give evidence of their presence, and we must devote special attention to these, as most closely connected with the subject which we have in hand.

The literature concerning these pathogenic forms in water is almost daily increasing: quite recently Tils§ has found *Staphylococcus pyogenes aureus* in town water.

Passing over the strong presumptive evidence that Koch's *Spirillum choleræ asiaticæ* is an aquatic form native to the waters in Bengal, it may be accepted that it occurs in water (tanks in India) as an occasional impurity.*

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* All these stand much in need of further investigation.

† See Winogradsky, "Ueber Eisenbacterien," 'Bot. Zeitg.,' 1888, p. 261. *Crenothrix polyspora* is merged into *C. Kühniana* by Zopf; but see Winogradsky, 'Beitr. z. Morph. u. Phys. d. Bakt.,' 1888.

‡ See Winogradsky, "Ueber Schwefelbacterien," 'Bot. Zeitg.,' 1887, pp. 489, *et seq.*, and 'Beitr. z. Morph. u. Phys. d. Bakt.,' 1888.

§ "Bacteriologische Unters. der Freiburger Leitungswässer," 'Zeitschr. f. Hyg., 1890, vol. 9, pp. 282—322.

Instances of the detection of the bacillus of typhoid fever (*Bacillus typhosus*, Eberth) in waters used for domestic purposes also seem to be established;† though it should be insisted on that great difficulties still stand in the way of directly recognising this species.‡

Of forms pathogenic to the lower animals, there have been found in water the bacterium which causes septicæmia in rabbits (*Bacillus cuniculicida*, Koch), which was originally met with in the waters of the River Panke, at Berlin, according to Koch.§

Rintaro Mori has also recorded the occurrence of three pathogenic species in the water of a certain drainage-canal.|| These are (1) *Bacillus murisepticus*¶ (Koch); (2) a form which Mori names "*Kapseltragender Canal-bacillus*," resembling in some respects Friedländer's *Bacillus pneumoniæ*, but not identical with it; and (3) a form, also unidentified as yet, which the author simply records as "Canal-bacillus." These forms or species were very constant in the drainage-canal water, and were proved to be pathogenic by infecting mice and guinea-pigs with them.

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* Koch, in 'Berliner Klin. Wochenschr.,' 1883–84; 'Bericht über die Thätigkeit der zur Erforschung der Cholera im Jahre 1883 entsandten Commission,' Berlin, 1887, p. 182. Nicati and Rietsch found the same spirillum during a cholera epidemic in the harbour of Marseilles ('Rev. d'Hygiène,' 1885, May 20).

† Loir, in 'Ann. d. l'Inst. Pasteur,' vol. 1, 1887, p. 488, and Cassedebat, in same Annals, vol. 4, 1890, pp. 625—640.

The typhoid bacillus (Eberth-Gaffky) was first detected in water by Moers ("Die Brunnen d. Stadt Mülheim a. Rhein vom Bakteriologischen Standpunkte aus betrachtet," 'Ergänzungshefte, Centralbl. f. allgem. Gesundheitspflege,' 2, 1886, p. 144); then by Michael in Dresden ("Typhusbacillen im Trinkwasser," 'Fortschritte d. Medizin,' 4, 1886, No. 11, p. 353); for the third time by Dreyfus-Brisac and Widal ("Epidémie de Fièvre Typhoïde, Considérations Cliniques et Recherches Bactériologiques," 'Gaz. Hebdom.,' 1886, No. 45); then, for the fourth time, by Chantemesse and Widal ("Enquête sur une Épidémie de Fièvre Typhoïde qui a régné à Pierrefonds, 1886," 'Rev. d'Hygiène,' 9, p. 116; 'Archiv. de Phys. et Pathol.,' 1887, p. 217); also by Reumer ("Zur Aetiologie d. Abdominaltyphus," 'Deutsche Mediz. Wochenschr.,' 1887, No. 28), as well as by others. For complete summary, see Jaeger, "Zur Kenntniss d. Verbreitung d. Typhus durch Contagion und Nutzwasser," 'Zeitschr. f. Hygiene,' 10, 1891, p. 197.

‡ Parietti has recently published a means for distinguishing it from the false forms. See 'Ann. de l'Instit. Pasteur,' vol. 5, 1891, p. 414.

§ 'Mittheil. aus d. Kaiserl. Gesundheitsamte,' 1881, vol. 1, p. 94.

|| "Ueber Pathogene Bacterien im Canalwasser," 'Zeitschr. f. Hygiene,' vol. 4, 1888, pp. 47—54.

¶ This had also previously been found in the water of the Panke (Gaffky-Loeffler, 'Mittheil. a. d. K. Gesundheitsamte,' 1, pp. 80 and 135).

§ II. *On some Relations between the Bacteriological Contents of Water and the Environment.*

Although the evidence on which the above statements are founded is of unequal value in different cases, it may be regarded as established that the germs of pathogenic Schizomycetes do occasionally occur in waters used for domestic purposes, and the records of medical literature fully bear out this conclusion.*

The next point for discussion is, How do these germs find their way into potable waters?

It seems capable of proof that water, as such, does not necessarily contain any bacteria at all, for if it is examined at the source of deep springs, or in the deep subterranean layers tapped by artesian well-pipes, it is found to be either wholly or practically free from organisms at or near the source. Moreover, it is an axiom that, in cases where the water-supply is drawn from rivers, there are more bacteria as we go towards the mouth, and fewer as we ascend the heights of the watershed; whilst the gain in bacteria, both as regards forms and numbers of individuals, is marked below each town or inhabited area through which the river flows.†

We now proceed to the questions, Why are the deep waters below the sub-soil free from germs? How do they become contaminated subsequently? And, what relations subsist between the facts elucidated and the questions concerned in our enquiry?

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* Especially for typhoid. See Vaughan and Novy ('Med. News,' 1888, p. 92), Charrin ('Ann. d'Hyg. Publique et de Méd. Légale, 1887, pp. 520—529), Brouardel et Chantemesse ('Ann. d. Hyg. Publ. et de Méd. Lég.,' 1887, No. 12), Hauser and Kreglinger ('Die Typhus Epid. in Triberg in den Jahren 1884 und 1885,' Berlin, 1887), and the literature already quoted.

† For more details in support of these statements, consult:—Burdon Sanderson ('Rep. of the Med. Officer of the Privy Council,' 1870 and 1872), Angus Smith ('Rep. Med. Officer Local Gov. Board,' 1884), Fol and Dunant ('Arch. des Sc. Phys. et Natur. de Genève,' 1884 and 1885), Di Vestea and Tursini ('Recherches sur les Eaux de Naples,' 1885), Cramer ('Die Wasserversorgung von Zürich,' 1885), Percy F. Frankland ('Monthly Reports to the Local Government Board on the Bacteriological Examination of the London Water Supply,' 1885—1888; also 'Journ. Soc. Chem. Industry,' 1885 and 1887; 'The Present State of our Knowledge concerning the Self-Purification of Rivers,' Internat. Congress of Hygiene and Demography, 1891), G. Bischof ("Notes on Dr. Koch's Water Test," 'Journ. Soc. Chem. Industry,' 1886), C. Fraenkel ("Unters. ü. Brunnendesinfection u. d. Keimgehalt d. Grundwassers," 'Zeitschr. f. Hyg.,' vol. 6, 1889, pp. 23—61), Koch ('Die Bekämpfung der Infections-Krankheiten: Rede zur Stiftungsfeier der Militärärztlichen Bildungsanstalten,' 1888, p. 25), Plagge and Proskauer ('Zeitschr. f. Hyg.,' vol. 2, 1887, p. 401), Wolffhügel ("Erfahrungen ü. d. Keimgehalt brauchbarer Trink- u. Nutz-Wässer," 'Arb. a. d. Kaiserl. Gesundheitsamt,' vol. 1, 1886, pp. 546—566), G. Frank ("Die Veränderung des Spree-Wassers innerhalb und unterhalb Berlin, &c.," 'Zeitschr. f. Hyg.,' vol. 3, 1888, pp. 355—403), Schlatter ('Der Einfluss des Ab-wassers der Stadt Zürich auf den Bacteriengehalt der Limmat," 'Zeitschr. f. Hyg.,' vol. 9, 1890, pp. 56—58). See also 'Ann. d. l'Instit. Pasteur,' vol. 3, 1889, pp. 559—569 and our Appendix A, *infra.*

The purity of the subterranean waters is certainly not due directly to the rain which falls on the land (and which is, of course, the original source of such waters) being devoid of germs; because, in the first place, much of this rain is already contaminated before it touches the soil, by bacteria suspended in the air, and secondly, because the instant that the rain touches any ordinary soil it becomes abundantly contaminated with micro-organisms.

So long as this water is near the surface of the soil, it forms, in fact, a medium admirably adapted for the growth and multiplication of the myriads of Schizomycetes and other organisms with which the surface soil teems.

It is this surface water flowing off the land into our rivers, open wells, &c., which so abundantly contaminates them by carrying with it, not only the microbes themselves, but also the soluble organic and mineral matters which serve them as food materials.*

As the rain water percolates into the land, however, more or less of it soon sinks to levels below those at which there is danger of its emerging as a contaminating fluid, and in this process of percolation two important changes take place. Firstly, as the water passes from the surface soil to the sub-soil, it leaves behind it both soluble and suspended matters: certain of its salts are retained in the films on the surfaces of the particles of earth, whilst other salts become dissolved in it; it is also, to a great extent, deprived of its dissolved oxygen, and a large proportion of its suspended germs are held back in the capillary interspaces.† In the subsoil, the water is in contact with Schizomycetes of quite different nature from those in the well-aërated surface soil, rich in organic and other food materials, and although these anaërobic organisms of the deeper layers are not necessarily less injurious, or otherwise, than the aërobic forms in the surface soil—we know far too little about them to say much as to the comparison—the water is falling more and more out of the dangerous stages.

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* See especially two admirable reviews by Duclaux, in 'Ann. de l'Inst. Pasteur,' vol. 4, 1890, on "Le Filtrage des Eaux," pp. 41—56; and "Sur les Relations du Sol et de l'Eau qui le traverse," pp. 172—184.

† Of the extraordinary power possessed by even thin strata of suitable filtering materials of arresting microbes present in the water passing through them abundant evidence has been furnished by one of us (Percy F. Frankland, "On the Removal of Micro-organisms from Water," 'Roy. Soc. Proc.,' 1885), as well as by Hesse ("Ueber Wasserfiltration," 'Zeitschr. f. Hygiene,' 1, 1886, p. 178), Pöhl ("Ueber Filtration d. Newa-wassers," 'Centralbl. f. Bakteriologie,' 1, 1887, p. 231), Bertschinger ("Untersuchungen über die Wirkung d. Sandfilter d. Städtischen Wasserwerke in Zürich," 'Vierteljahrsch. d. Naturforsch. Gesellschaft in Zürich,' 34, 1889), C. Fraenkel and C. Piefke ("Versuche über die Leistungen d. Sandfiltration," 'Zeitsch. f. Hygiene,' 8, 1890, p. 1), C. Piefke ("Aphorismen über Wasserversorgung, Einrichtung und Betrieb von Filteranlagen," 'Zeitsch. f. Hygiene,' 8, 1890, p. 331), Proskauer ("Die Reinigung v. Schmutzwässern nach dem System Schwarzkopf," 'Zeitschr. f. Hygiene,' 10, 1891, p. 51). See our Appendix A.

At still deeper levels, even these anaërobic forms are left behind, and the thoroughly filtered liquid may now subside into a closed subterranean basin, where it may remain pure for any length of time,* so far as living organisms are concerned, provided no fissures or direct prolongations of surface waters allow of contamination from above.†

It is obvious from the foregoing that the two great sources of contamination of our water-supplies are the air and the surface waters.‡

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* The remarkably impure deep well water examined by Rohn and Wichmann ('Mitth. d. Oesterr. Versuchstat. f. Brauerei u. Malzerei,' H. 2) must surely have been connected with surface waters!

† A recent examination (1891) made by one of us of the water from deep wells in the chalk of the Kent Waterworks Company showed the number of micro-organisms revealed by the gelatine test to vary from 4 to 76 and to average 32 in 1 cubic centimeter. In all cases the water was taken directly from the pumps and before it had undergone any storage.

For collected results of the bacteriological examination of spring and well waters, see especially Hueppe ("Die hygienische Beurtheilung d. Trinkwassers vom biologischen Standpunkte," Schilling's 'Journ. f. Gasbeleuchtung und Wasserversorgung,' 1887), also Tiemann-Gärtner ('Untersuchung. d. Wassers,' Braunschweig, 1889, p. 498).

‡ It is hardly necessary now to insist on the importance of the air, and its dust, in this connexion. Reference may be made to the following in confirmation:—Angus Smith ('Air and Rain,' 1872), Tyndall ('Floating Matter of the Air,' 1881); Percy F. Frankland ("The Distribution of Micro-organisms in Air," 'Roy. Soc. Proc.,' 1886, No. 245, p. 509; "Some of the Conditions affecting the Distribution of Micro-organisms in the Atmosphere," 'Soc. of Arts Journ.,' 1887, vol. 35, p. 485; "A new Method for the Quantitative Estimation of Micro-organisms in the Atmosphere," 'Phil. Trans.,' 1887, B, p. 113); Grace C. and Percy F. Frankland ("Studies on some new Micro-organisms obtained from Air," 'Phil. Trans.,' 1887, B, p. 257); Percy F. Frankland and T. G. Hart ("Further Experiments on the Distribution of Micro-organisms in Air," 'Roy. Soc. Proc.,' vol. 42, 1886, p. 267); Miquel ('Annuaire de l'Observatoire de Montsouris,' 1877 to 1891, and 'Manuel Pratique d'Analyse Bactériologique des Eaux,' 1891). Also Aitken in 'Proc. Roy. Soc. Edinb.,' vol. 16, 1886, p. 139; 'Trans. Roy. Soc. Edinb.,' vol. 15, February 6, 1888; and as regards contamination by surface waters see Koch ('Rede zur Stiftungsfeier der militärärztlichen Bildungsanstalten,' 1888, p. 25), Plagge and Proskauer ('Zeitschr. f. Hyg.,' vol. 2, p. 479), Soyka ('Deutsche Vierteljahrschr. f. öffentl. Gesundheitspflege,' 1888, p. 638), Wolffhügel ('Arb. a.d. Kaiserl. Gesundh.-amte,' 1886, p. 546), and Fraenkel ('Zeitschr. f. Hyg.,' 1889, p. 23).

As regards filtration, Percy F. Frankland ("On the Removal of Micro-organisms from Water," 'Roy. Soc. Proc.,' 1885, "New Aspects of Filtration and other Methods of Water Purification: The Gelatine Process of Water Examination," 'Journ. Soc. Chem. Ind.,' 1885; "Water Purification: its Biological and Chemical Basis," 'Proc. Institut. of Civil Engineers,' vol. 85, 1885–86; "Filtration of Water for Town Supply," 'Trans. of the Sanitary Institute of Great Britain,' vol. 8, 1886;

It is also clear that pathogenic forms find their access to such waters by the same routes as saprophytic and harmless ones, a point of primary importance when we reflect on the danger of such being in the air and the drainage of inhabited areas. That the spores of *Bacillus anthracis* find their way from the bodies of animals to the surface waters of meadows, and thence into rivers, must be accepted as proved by the researches of Pasteur and Koch,* and our knowledge in this connexion suggests only too plainly what may occur in other cases, thus explaining the observed facts that the microbes of typhoid, cholera, septicæmia, &c., do occur in exposed waters; and connecting the presence of other pathogenic forms, known to be cast off in secretions, dejecta, &c., with the suspicions aroused from the washing of milk vessels, &c., with such waters.

It is necessary to bear in mind, however, that although the vista of possibilities here opened out is a real one, most of the bacteriological examinations of water support the conclusion that by far the majority of the Schizomycetes met with in natural waters are harmless, or at least are not capable of producing disease directly in those who drink the waters.

Such conclusions have led to speculations, in different directions, as to why the bacteriological examination of waters has, so far, seldom led to the detection of pathogenic forms, although such waters are exposed to contamination.

Firstly, it is possible that a Schizomycete should lose its virulence or be weakened, or even die, when transferred from a suitable medium into one so thin and innutritious as any ordinary potable water would be; secondly, quite apart from the scarcity of food materials, it requires some reflection to thoroughly grasp how great must be the changes in the circumstances which a given pathogenic form—say, the anthrax bacillus, for argument—meets with when it leaves the living

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"Recent Bacteriological Research in connection with Water Supply," 'Journ. Soc. Chem. Ind.,' 1887; "The Applications of Bacteriology to Questions relating to Water Supply," 'Trans. Sanitary Institute of Great Britain,' vol. 9, 1887); H. A. Nielsen ("The Bacteria of Drinking Water, in particular as regards the Species in the Water Supply of Copenhagen," Copenhagen, 1890; see 'Ann. d. l'Inst. Pasteur,' 1890, p. 41), Bertschinger ('Vierteljahrschr. d. Naturf. Gesellsch.,' vol. 34, 1889, also 'Ann. de l'Inst. Pasteur,' vol. 3, 1889, p. 692), Duclaux ("Le Filtrage des Eaux," 'Ann. de l'Inst. Pasteur,' 1889, pp. 41-56; and "Sur les relations du Sol et de l'Eau qui le traverse," 'Ann. de l'Inst. Pasteur,' 1889, pp. 172–184); also our Appendix A.

As to bacteria in ice, snow, and hail, see Prudden ('New York Med. Record,' 1887), Bordoni-Uffreduzzi ('Centralbl. f. Bakt. u. Parasitenkunde,' vol. 2, 1887), Janowski (*ibid.*, vol. 4, p. 547), and Schmelck (*ibid.*, vol. 4, p. 545), Fraenkel ('Zeitschr. f. Hyg.' vol. 1, pp. 302—314), and Odo Bujwid ('Ann. de l'Inst. Pasteur,' vol. 1, 1887, p. 592).

* Pasteur, 'Bull. de l'Acad. de Médecine,' 1880; Koch, 'Mittheil. a. d. K. Gesundheitsamte,' 1881, p. 49.

body of a sheep and is carried into a stream. In considering this example, the observed facts as to the susceptibility of anthrax to low temperatures should be borne in mind. The great reduction in temperature would alone suffice to impress it with effects very different from those of its previous environment—the tissues of a warm-blooded animal—and matters would be made no simpler by the differences in exposure to the oxygen of the air, the light of the sun, and so forth.*

That such a view is not without foundation is sufficiently proved by recent researches on the action of heat, light, and oxygen on this very bacillus in question.

To take the case of temperature first. It is generally agreed that *Bacillus anthracis* cannot go on growing and dividing below about 15° C., nor above about 45° C., and that it thrives best at some temperature near 35° C.; it is also agreed that it is markedly susceptible to the presence of free oxygen in its normal development. Although undoubtedly favoured by presence of oxygen, the anthrax bacillus will grow in the presence of only a very small quantity of air, (Liborius, 'Zeitschr. f. Hyg.,' 1, p. 170). Under favourable circumstances, but only if oxygen is present and the temperature fairly high, the bacilli form spores in their interior. This complicates the matter under discussion, for these spores are sometimes capable of remaining uninjured for long periods under conditions which would inevitably kill the vegetative rodlets.

Now Roux† has lately shown that in a given culture containing these spores some individuals are more resistant than others, and that when germinating it is of importance to a given spore whether it is near the surface of a liquid or deeper down; that at high temperatures, in contact with free atmospheric oxygen, the virulence of a given culture can be attenuated,‡ though no such attenuation results when out of contact with air.

These are by no means all the facts that have to be regarded, however.

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* Possibly by far the most important of the destructive influences of fresh water on such microbes is that of the change in the conditions of osmosis, which is also entirely substantiated by experiment, and is in harmony with what we know of the physiology of living tissues (see Marshall Ward, "On Some Relations between Host and Parasite," &c., the Croonian Lecture for 1890, 'Roy. Soc. Proc.,' vol. 47, pp. 393—443, and references to the works of Pfeffer and De Vries therein; also Fischer, "Die Plasmolyse der Bacterien," in 'Ber. üb. d. Verhandl. Sächs. Gesellsch. Wiss. zu Leipzig,' vol. 1, 1891, pp. 52—74, and Wladimiroff, "Osmotische Vers. an lebenden Bakterien," in 'Zeits. Physik. Chem.,' vol. 7, pp. 529—543).

† Roux, "De l'Action de la Chaleur et de l'Air sur les Spores de la Bactéridie du Charbon" ('Ann. de l'Inst. Pasteur,' vol. 1, 1887, pp. 392—399).

‡ We ought to deal with this subject very cautiously, for others have stated, and some confuted, this previously; but of course we are not concerned with all the details here.

A large number of investigators, by means of researches first started by Downes and Blunt in 1877,* in this country, and carried on ever since by others, have shown that the action of the sun's rays has to be taken into consideration when dealing with questions of the vitality or rate of growth, &c., of the spores and rodlets of this and other Schizomycetes.

The controversy is too long for full treatment in this report, but the upshot of the whole may be summed up as follows. Certain rays of light, apparently more especially those known as the "chemical rays,"† so affect the germinating spores of certain bacteria (*Bacillus typhosus*, *Bacteria anthracis*), in presence of air, that their growth is inhibited. The presumption is that the solar rays enhance certain oxidation processes in the living protoplasm, but questions also arise in some cases as to possible effects on the nutritive media as well, though Janowski certainly seems to have eliminated these in his cultures of the typhoid bacillus.‡

A second possible view as to the fate of a given species of bacterium when suddenly washed into a stream is that it remains there unaltered, and that the chances are so enormously against its being detected, or (what, from some points of view, is the same thing) against its finding a suitable nidus in a living animal, that it simply wanders passively in the waste of waters surrounding it for an indefinite period, or until it reaches the sea.

This view also must be faced as one not altogether unsupported by observations, but only on the understanding that the microbe is in the spore stage, or, at least, passes into that condition soon after reaching the water, for the weight of bacteriological experience is distinctly against the probability of a living Schizomycete, in the simple vegetative condition, remaining as such for any length of time, at any rate in such a dilute medium as potable water.

With spores the matter is different. Duclaux found old spores of certain forms which had been kept out of contact with air for several years to be still capable of germination when sown in suitable media,* and it is well known what extremes of temperature, &c., spores *can* withstand. At the same time, since the rule is that a spore germinates in even dilute solutions, when transferred thither, in presence of oxygen and if the temperature rises, it may be regarded as probable that, for aërobic bacteria at any rate, the changing conditions in a river, &c., will prevent its remaining merely passive—all available evidence is rather in favour of its either growing or else dying if it cannot adapt itself to the circumstances, although the death of spores may be delayed for many months and possibly even longer.

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* Downes and Blunt, 'Roy. Soc. Proc.,' 1877, p. 488, and *ibid.*, 1878, p. 199.

† It should be clearly indicated, however, that the evidence goes rather to show that it is *insolation* which produces these results, and not diffused light. Insolation can have practically no effect in natural waters.

‡ For details as to the action of light on bacteria, consult Raum ("Der Gegenwärtige Stand unserer Kenntnisse ü. d. Einfluss des Lichtes auf Bacterien, &c.," 'Zeitschr. f. Hyg.,' vol. 6, 1889, pp. 312—368), for full references to literature to date. Then see Pansini ("Action de la Lumière Solaire sur les Microorganismes," in 'Rivista d'Igiene,' 1889; also 'Ann. de l'Inst. Pasteur,' vol. 3, 1889, p. 686); Janowski, ("Zur Biologie der Typhus-bacillen," in 'Centralbl. f. Bakt. u. Parositenk.,' 1890, Nos. 6—8); F. Elfving, 'Studien über die Einwirkung des Lichtes auf die Pilze,' Helsingfors, 1890, 139 pp. and 5 plates—deals more especially with fungi proper—and our Appendix A.

Indeed, recently, strong evidence has been produced, showing that pathogenic microbes may sink to the bottom of lakes and rivers and there remain in a living state, amongst the sediment or mud, for very long periods of time, until in fact, some flood or other disturbance causes them to become once more suspended in the water, when they may be carried by a stream or current to another place. It is obvious that this hitherto but little recognised factor is of the very highest importance in connexion with the supply of water from rivers subject to objectionable pollution.†

A third view is possible, viz., that the Schizomycete finds the new environment at least not unsuited to its immediate requirements, and that it grows and multiplies more or less successfully in the large mass of water.

This unquestionably happens with some forms, which, as we have seen, are so well adapted for life in rivers, ponds, and even pipes, that they have long been known as aquatic species.‡ As has been stated, and will be seen more clearly shortly, however, this is also true, to a limited extent, of many forms, including certain pathogenic species, which are only met with in natural waters as intruders; they are able to maintain themselves alive for variable periods, and then usually succumb.

Before passing to this part of the subject, we wish to remark upon the method for a long time employed in the bacteriological examination of water, and on some of the general results obtained.

Since 1881 it has been almost universally the custom to employ the gelatine-plate cultures as devised by Koch. A measured small quantity of the water to be examined is added to the nutrient gelatine, kept fluid at about 35° C., and the mixture, after solidification in a thin layer, is incubated generally at a temperature of 20—22° C. in contact with air, but protected from danger of contamination: we need not go into the particular methods of sterilisation, protection, incubation, &c.; suffice it to say that in a few hours or days colonies of bacteria appear on the culture plates, and the number of individual bacteria in the measured sample of water is estimated from these, on the assumption that each colony has sprung from one germ.

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* Quoted by Roux ('Ann. de l'Inst. Pasteur,' vol. 1, 1887, p. 392).

† Lortet and Despeignes, "Recherches sur les Microbes Pathogènes des Eaux Potables distribuées à la Ville de Lyon" ('Rev. d'Hygiène,' 12, 1890, No. 5); also Lortet, "Die pathogenen Bakterien d. tiefen Schlammes im Genfer See" ('Centralbl. f. Bakter.,' 9, 1891, p. 709).

‡ This term is, of course, not quite accurate, in view of the fact that *all* Schizomycetes must have water to grow; and are, indeed, descended from aquatic forms—lower Algæ.

The comparison of numerous researches made in recent years, and the experience gradually being gained in all branches of the *technique* of the subject, have slowly led to the detection of numerous fallacies in the almost established mode of procedure.

In the first place, it was soon apparent that the mere *numbers* of bacteria, per cubic centimetre of water, are in no sense a satisfactory guide to the fitness of such water for domestic purposes; it may be quite true that one revolts from a water proved to yield large numbers of colonies of bacteria, and one can understand that a water yielding even 500 colonies per cubic centimetre should be preferred to one yielding, say, 5000 colonies per cubic centimetre, but, so long as this choice is based on the assumption that mere numbers decide the safety or danger of the water, it is utterly fallacious. The 500 colonies may contain some which have been developed from pathogenic germs, while the 5000 may have all arisen from harmless forms. This consideration entirely invalidates all the older conclusions, which were made in some quarters, as to a given water being good or bad according as it yields few or many colonies per cubic centimetre on plate cultures; the only test is to determine *what* the bacteria of the different colonies are, and the only general deduction of any value to be drawn from mere quantitative bacteriological determinations is, that a water obviously containing a number of different species is, on the whole, more likely to have been subjected to contamination than one which contains but few different kinds.

A water should be suspected, therefore, and subjected to further examination, if it yields several different kinds of colonies unknown to the investigator.

As a matter of practical experience, it is certainly impossible to rapidly identify more than a few colonies in such cultivations; if a complete investigation of the life histories, &c., of all the forms were attempted, the bacteriological examination of a single sample of water might take years, and consequently this part of the subject is the one which awaits and invites the attention of numerous and energetic, properly equipped workers.

Then as to the primary assumption which lies at the base of all the older plate cultures. This was that each colony has taken origin from *one* germ, isolated at the time of infecting the gelatine, and which developed in the medium during the period of culture.

In the first place, the conclusion that each colony has sprung from one germ is a mere assumption, and it is to be viewed with suspicion at the outset. Cramer* showed that bacteria have a habit of sticking together in the water, and several other observers† have shown that this is a real danger in all bacteriological analyses, and that individual colonies often result from the growth, &c., of not one, but many agglomerated spores or segments. Many observers have attempted to get over this difficulty by shaking the sowing in distilled water, before infection. Wolffhügel and Riedel suggest the possibity that there are dangers connected with this method also, *e.g.*, removal of gases, oxidation, &c. It is even asserted that prolonged‡ mechanical shaking affects the growth of bacteria, but this concerns the transit, &c., of cultures rather than the point under discussion.

It has been suggested that the best method for ensuring separation from one another of the bacteria would be to pass the water through sterilised glass wool, as Elfving did for spores of fungi ;§ only there would be some loss. Thoroughly sterilised cotton wool, or even filter papers, may be used, but there is danger of washing traces of soluble substances from these.

The question as to whether the colonies result from a single germ or from an agglomeration is, after all, not a matter of such grave importance as might at first sight appear, for if the precaution be taken, as it invariably should be, of violently agitating the sample of water immediately before making a plate cultivation, it is obvious that any conglomerate which may be present and does not yield to this treatment is, for practical purposes, a single source of infection, and will thus give rise to a single colony.

Another difficulty with plate cultures is due to some species causing liquefaction of the gelatine through the action of peptonising ferments which they produce: this causes local floodings, and the running together of neighbouring colonies, or the submergence of some of them, and seriously interferes with the counting and estimation of the numbers.

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* 'Kommissions-bericht über die Wasserversorgung von Zürich und ihren Zusammenhang mit der Typhus-epidemie des Jahres 1884,' Zürich, 1885, p. 92.

† Malapert-Neufville ('Zeitschr. f. analyt. Chem.,' vol. 25, 1886, p. 39), Wollfhügel and Riedel ("Die Vermehrung der Bacterien im Wasser," 'Arb. a. d. K. Gesundheitsamte,' vol. 1, 1886, pp. 455—480) ; also Fol and Dunant ('Revue d'Hygiène,' 1885, vol. 7, p. 183).

‡ It may be assumed that the shaking carried on for a few minutes only before making a culture can have no effect on the life of the microbes ; even the effect of long-continued shaking is very doubtful, the evidence being quite conflicting. On this point see Horvath ('Pflüger's Archiv f. Physiol.,' vol. 17, 1878, p. 125), Naegeli ('Theorie d. Gährung,' 1879, p. 88), Reinke ('Pflüger's Arch. f. Physiol.,' vol. 23, 1880, p. 434), Büchner ('Sitzungsber. d. K. Bayer. Akad. d. Wiss.,' 1880, pp. 382 and 406), Wernich ('Desinfectionslehre,' 1880, p. 74), and further literature in these.

§ Elfving used cotton-wool ('Studien ü. d. Einwirkung des Lichtes,' p. 31). See also Geppert ('Ann. de l'Inst. Pasteur,' vol. 3, p. 673), who used glass.

The only mode of combating this difficulty consists in using such a volume of the infecting water as will yield a manageable number of such centres of liquefaction.

But these are by no means the only sources of fallacy incidental to the methods of gelatine-plate cultures. It has been implied by some of the earlier workers, rather than definitely assumed, that all the living germs in the sample of water mixed with the nutrient gelatine* will give rise to colonies, provided the plate culture is thin enough to ensure the access of oxygen to all parts, the sample small enough to ensure isolation of the individual bacteria or spores, and the temperature a suitably high one to promote rapid growth, without preventing the proper solidification of the medium.

As matter of fact, there are serious fallacies traceable to all these implications. Many bacteria are now known which are incapable of growing in presence of the oxygen of the air, while others will only withstand partial pressures of that gas; it may be safely concluded that the gelatine-plate cultures give no account whatever of these forms, although they may and often do occur in tap waters,† &c.

Moreover, even the thinnest layer of gelatine may so far hinder the access of oxygen to completely submerged aërobic forms as to retard their growth, and so they become dominated by the more rapid development of other colonies. This domination is not necessarily due to the mere flooding of the suppressed forms with liquefied gelatine: Garré‡ showed a short time ago that some bacteria, growing on gelatine side by side with other species, can inhibit the life-actions of the latter by the poisonous influence of their metabolic products, and Miquel§ claims to have proved similar actions in water, and even to have isolated the toxic principles, and rendered other water immune by their aid.

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* The quality of gelatine and peptone varies also. For hints in this connexion see Reinsch, "Zur bakteriolog. Unters. des Trinkwassers" ('Centr. f. Bakt.,' vol. 10, 1891, p. 415).

† A good instance has recently been investigated by Perdrix ("Sur les fermentations produites par un Microbe anaérobie de l'Eau," 'Ann. Inst. Pasteur,' vol. 5, 1891, pp. 286—311).

‡ "Ueber Antagonisten unter den Bakterien" ('Correspondenzbl. f. Schweizer. Aerzte,' Jahrg. 17, 1887). Also Blagovestchensky ("Sur l'Antagonisme entre les Bacilles du Charbon et ceux du Pus Bleu," 'Ann. de l'Inst. Pasteur,' 1890, vol, 4, pp. 689—715).

§ "Dixième Mémoire sur les Poussières organisées de l'Air et des Eaux" ('Annuaire de l'Observatoire de Montsouris,' 1888), and 'Manuel Pratique d'Analyse Bactériologique des Eaux,' 1891, pp. 153—155.

Again, as is well known, there are several forms which will not grow on gelatine at all,* and there are others which grow so slowly that they will not be counted in the estimations made by gelatine-plate cultures, either because the colonies formed in the time are too small to be seen, or because they succumb to dominant forms—for it must never be forgotten that, among competing Schizomycetes, it is especially the early forms which gain the advantage, as elsewhere in nature.

Finally, since the temperature has been shown to be such a determining factor in the growth and multiplication of bacteria, we may be sure that this item affects these plate cultures also, and it is well known that different numbers are obtained according to the temperature of incubation, and with reference to this point it is especially to be noted that the optimum temperatures for different bacteria may differ considerably.†

Taking all the facts into consideration, therefore, it is necessary to regard the gelatine-plate method as an imperfect one at best. But if we inquire whether there is a better one, we are bound to reply that there is not, at any rate for general purposes; but for special requirements it is possible to devise several modified methods for the culture of particular forms, and this has been done in certain cases.

§ III. *The Vitality of Micro-Organisms in Water.*

It is now time to enter upon the special literature dealing with the behaviour of selected forms of Schizomycetes in particular samples of water, and we propose to treat this somewhat more in detail, and in chronological order, so far as possible, because it bears directly on the subject of our enquiry.‡

This invesigation followed as the natural corollary to the discovery that some micro-organisms can multiply to a most extraordinary extent in waters almost entirely destitute of organic matter, like distilled water. The first recorded instance of such multiplication in distilled water was made by one of us in 1885,* on which occasion it was found that in the course of forty-eight hours the number of microbes had increased from 1073 in the cubic centimetre to 48,100 in the same volume. Similar instances of multiplication in the pure spring water supplied to Munich were published shortly afterwards, by Leone,† whilst the same phenomenon was observed by Cramer‡ in the case of the microbes present in the waters of the Lake of Zurich.

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* Some of these are of the highest importance in connexion with the chemical changes taking place in natural waters, *e.g.*, the nitrifying organisms (Percy F. and Grace C. Frankland, "The Nitrifying Process and its Specific Ferment," 'Phil. Trans.,' 1890, B, p. 107; Winogradsky, 'Ann. de l'Inst. Pasteur,' 1890 and 1891; Warington, 'Chem. Soc. Journ.,' 1891, p. 484).

† In this connexion it should be noted that the range of temperature for different bacteria is much larger than is commonly assumed. There are species which will grow at 0° C., and there are others which grow at temperatures as high as 50—70° C. See Fischer ("Bakterienwachsthum bei 0° C., &c.," 'Centr. f. Bakt.,' vol. 4, 1888, p. 89), Globig ('Zeitschr. f. Hyg.,' vol. 3, p. 294), Forster ('Centr. f. Bakt.,' vol. 2, p. 337), Miquel ("Monogr. d'un Bacille vivant au-delà de 70° C.," 'Ann. de Micrographie,' Année I, Paris, 1888, pp. 4—10).

‡ See Appendix C, p. 268.

Similar phenomena formed the subject of more extensive investigations contained in three memoirs, which appeared almost simultaneously in 1886 by Wolffhügel and Riedel,§ by Meade Bolton,‖ and by one of us.¶ Each of these not only confirmed the rapid and extensive multiplication of microbes, even in the purest natural waters, but differed from the predecessors in recording the results of experiments in which specific pathogenic forms were introduced into natural waters of different kinds, including sewage. It will be convenient to discuss, in the first instance, these three contributions to the subject along with another by Heraeus, which appeared shortly afterwards.

In Meade Bolton's paper,** after referring to the literature regarding the general bacterial contents of ordinary waters, and criticising the various methods hitherto in vogue, the following generalisations are made :—

1. Ordinary waters always contain some bacteria.
2. The numbers of individuals and species vary in different waters, and from time to time.
3. Certain forms predominate, because they can multiply readily in such waters, as is proved by their rapid increase when the water is allowed to stand for a few days.
4. After the climax of increased numbers has been obtained, the bacteria gradually diminish in quantity.

Bolton established the truth of these conclusions, and showed that the growth and increase of these water bacteria differ according to the kind of water, the temperature and other external conditions remaining the same.

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* Percy F. Frankland, "The Removal of Micro-organisms from Water," 'Roy. Soc. Proc.,' vol. 38, 1885, p. 387.

† "Sui Micro-organismi delle Acque Potabili, loro Vita nelle Acque Carboniche," 'Rendiconti della R. Accademia dei Lincei,' 4 Ottobre, 1885; 'Chem. News,' vol. 52, p. 275.

‡ 'Die Wasserversorgung von Zürich, ihr Zusammenhang mit der Typhusepidemie d. Jahres 1884,' Zurich, 1885.

§ 'Arbeiten a. d. K. Gesundheitsamte,' vol. 1, pp. 455—480.

‖ 'Zeitschr. f. Hyg.,' vol. 1, p. 76.

¶ Percy F. Frankland, "The Multiplication of Micro-organisms," 'Roy. Soc. Proc.,' vol. 40, 1886, p. 526.

** "Ueber das Verhalten verschiedener Bakterienarten im Trinkwasser" ('Zeitschr. f. Hyg.,' vol. 1, 1886, pp. 76—114).

He gives examples showing that the increase is most rapid, as a rule, during the first thirty-six hours, and then a diminution sets in, day after day, ending in the water containing a smaller number than at first.

This gradual diminution was not due to mere precipitation, but was, perhaps, in part to be accounted for by the coherence of the germs in clumps, and in part to actual death.

He then isolated and described sixteen of the commonest species, which were shown to actually grow and multiply in ordinary drinking waters.

Two of these forms were shown to be capable of easy multiplication in such waters, and that quite independently of the chemical constitution of the waters. He found that they flourished in the purest distilled water he could obtain, as well as in "bad" water, and assumes that this is because the very small amount of organic nutriment they demand* is never absent.

Bolton concluded from his experiments that variations of temperature, and in the amount of oxygen dissolved in the water, were far more important factors than the chemicals dissolved in ordinary waters. In this conclusion, however, he is neither supported by his own nor the previous experiments of Leone, for it was found by both that the multiplication was almost equally rapid if a stream of hydrogen or a stream of air was passed through the water.

He further inferred that, in practice, the accumulation of bacteria in pipe waters is due to the multiplication of forms (carried in by surface drainage in the first instance) in the standing water as the temperature rises.

He then tried the effects of (1) distilled water, (2) common drinking waters, and (3) badly contaminated waters, on specific pathogenic and other bacteria, obtained from pure cultures and added to the waters with as little traces of the culture medium as possible. In many of his experiments, however, he has apparently failed to secure this last-named condition, as in most cases the number of organisms introduced into the particular waters is recorded as "un-countable," thus clearly pointing to insufficient dilution before inoculation. To save repetition it must be mentioned that all of Bolton's experiments were made with waters previously sterilised by heat.

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* It is, however, much to be regretted that in not a single instance is the chemical composition of any of these waters recorded by the author.

It may be observed here that we cannot accept, without reserve, general statements to the effect that *pure* water is capable of supporting the life of bacteria. Miquel shows how such water, which may be obtained in quantity by simple condensation ('Analyse Bact. des Eaux,' p. 156), is incapable of supporting bacterial life (pp. 157—158).

He found that spore-free bacilli of *Bacillus anthracis* rapidly die off in tap water; whereas, in the condition of spores, this organism may remain alive in such waters for nearly a year.

Staphylococcus pyogenes aureus may live for from ten to twenty, to upwards of thirty days in ordinary and bad waters respectively.

Micrococcus tetragenus rapidly disappeared in every case in less than four to six days.

Bacillus typhi abdominalis lived in some cases upwards of fourteen days in the absence of spores, and upwards of thirty to forty days in the form of spores.

In all these cases the two most important factors were the presence of spores and the temperature; the bacteria were eliminated the more rapidly the higher the temperature; they resisted the longer the more they had matured their spores. This was true, assuming that no proteids or other assimilable organic bodies were added to the water.

None of Meade Bolton's experiments were made with simultaneous presence of water bacteria: on the whole, subsequent researches have shown that the presence of forms which easily flourish in ordinary waters hurries the elimination of the intruding pathogenic forms.

Heraeus,* in his general conclusions supports those of Meade Bolton in most of the important respects, and especially the rapid increase of individuals of the bacteria in ordinary waters. He insists on the fact that certain forms multiplied in solutions absolutely devoid of organic materials.

At the same time, he concludes from his experiments that a "bad" water suits the bacteria better than good drinking water; and this conclusion is of course in accordance with all ordinary experience, since a "bad" water contains relatively much organic matter.

The important paper by Wolffhügel and Riedel,† which may next be examined, is full of excellent hints on methods, and of references to work bearing on the subject, and contains several valuable warnings as to sources of error in such investigations. The authors insist that the composition of the water is of importance, and in this respect place themselves in direct antagonism to Meade Bolton.‡ They employed both pathogenic and non-pathogenic bacteria, and sterile as well as normal waters.

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* "Ueber das Verhalten der Bacterien im Brunnenwasser, sowie über reducirende und oxydirende Eigenschaften der Bacterien" ('Zeitschr. f. Hyg.,' vol. 1, 1886, pp. 193—234).

† "Die Vermehrung der Bacterien im Wasser" ('Arb. a. d. Kaiserl. Gesundheitsamte,' Berlin, 1886, vol. 1, pp. 455—480).

‡ We may here emphasise our previous note that most investigators disagree with Meade Bolton in this respect, and we may conclude that the latter lays too little stress on the constitution of the water.

These authors prove that very minute traces of organic materials in a water induce rapid multiplication of certain species, that the temperature and quiescence of the water are important, and discuss the question as to the effects of mechanical shakings* of the waters, *e.g.*, in transit. They leave this matter undecided, but are of opinion that it will have to be reckoned with by bacteriologists.

As regards pathogenic species, they found that *Bacillus anthracis* multiplied in the dirty water of the River Panke, both normal and when sterilised by heat,† so long as the temperature was high enough (12—15° C. to 30—35° C.); but that at low temperatures the bacilli did not flourish, and even died off.

Typhoid bacilli ("ileo-typhus") lived for some time, and even multiplied, in (sterilised) ordinary drinking water, as well as in the (sterilised) bad waters. In distilled water they gradually died out, though they may require twenty days or more to do so. In non-sterilised waters they found that they grew so slowly that they were swamped by other forms on the gelatine-plate test-cultures, thus showing how difficult it is to obtain a satisfactory result in such experiments.

To obviate this difficulty they placed the typhoid bacillus in selected waters, containing *selected* water bacteria, and they then found that it lived so long that they felt constrained to warn us that this dangerous form may maintain itself for weeks: they also prove that milk‡ is a good vehicle for it, and that the belief in the danger of washing milk-cans with water containing typhoid bacilli is a well founded one.

Cholera spirilla were found to maintain themselves for seven days at least in all kinds of sterile waters, and to be still present in some cases even after eighty-two days. In unsterilised waters, however, this form is soon overcome. Here, as in other cases, the temperature was found to be important.

A curious result is worth noting. They found that the cholera spirilla take some time to accommodate themselves to the exigencies of a water containing competing forms, and consequently the latter usually dominate and eliminate the former. But in certain cases the cholera spirilla do accommodate themselves to the circumstances for a time, and if such specimens be then removed and placed in a fresh sample of the water they multiply at once, and are much more resistant to the water bacteria among which they find themselves.

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* With full reference to previous literature.

† None of the experiments were made with water sterilised by *filtration* only.

‡ See also W. Hesse ("Unsere Nahrungsmittel als Nährböden für Typhus und Cholera," 'Zeitsch. f. Hyg.,' vol. 5, 1889, p. 527); Kitasato ("Das Verhalten der Cholerabacterien in der Milch," 'Zeitsch. f. Hyg.,' vol. 5, 1889, p. 491); Almquist ("Neue Erfahrungen über Nervenfieber und Milchwirthschaft," 'Zeitschr. f. Hyg.,' vol. 8, 1890, p. 137).

In distilled water the cholera spirilla usually died off rapidly,* but cases happened where they lived for thirty-three days; possibly the distilled water contained impurities in these cases.

The authors insist on the danger of cholera germs in water, and expecially in ordinary river, well, and tap waters, which showed the presence of living cholera germs *seven months after infection.*

In the paper by one of us† the particular waters submitted to examination were those of the rivers Thames and Lea before and after filtration by the several London Companies, as well as the deep-well water from the chalk supplied by the Kent Company. It was found that the microbes in the unfiltered waters underwent but little multiplication, and in some cases very considerable diminution, on standing at the ordinary temperature of the air, whilst at a temperature of 35° C. very rapid multiplication took place, which was followed by subsequent decline. In the case of the filtered river waters, on the other hand, there was invariably a large increase, especially at the high temperature, also followed, however, by a subsequent decline. By far the most rapid multiplication was observed in the case of the organically pure deep-well water; thus on one occasion the numbers rose from 7 to 495,000 in the course of three days when the water was kept at 20° C.; the tendency to a subsequent decline was, however, also exhibited. On these surprising results the author points out that the deep-well water is at the outset almost wholly free from micro-organisms, and that it has never before been inhabited by such living matters, and that it is only reasonable to infer, therefore, that those of its ingredients which are capable of nourishing the particular micro-organisms which flourish in it are wholly untouched, whilst in the case of the river waters, the most available food supply must have been largely explored by the numerous generations of micro-organisms which have inhabited them. Further, he remarks that the number of different varieties of micro-organisms is far greater in the case of the river waters than in that of the deep-well water, and that in the latter case, therefore, the organisms present will probably have a freer field for multiplication than in the presence of competitors, some of which may not improbably give rise to products which are hostile to others.

In a similar manner he explains the greater capacity for multiplication exhibited by the filtered as compared with the unfiltered river water, for by the process of filtration the number of different varieties of micro-organisms is largely reduced, as is at once seen by the inspection of the plate cultivations, and those varieties which remain have, therefore, a more favourable opportunity for reproduction than in the presence of more numerous varieties.*

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* As the authors point out, this agrees with Babes' results (Virchow's 'Arch. f. Path. Anat.,' vol. 99, 1885, p. 152), and contradicts those of Nicati and Rietsch ('Revue d'Hyg.,' 1885, No. 5, p. 353). Since the latter employed liquid cultures of the bacilli, they probably introduced food materials into the water.

† *Loc. cit.*, p. 471.

The specific forms experimented with were the *Bacillus pyocyaneus* (from green pus), Finkler-Prior's *Spirillum*, and Koch's *Spirillum of Asiatic cholera;* they were in all cases introduced into sterilised waters only.

The *Bacillus pyocyaneus* was found to multiply extensively in distilled water, filtered Thames water, deep-well water, and London sewage. Finkler-Prior's *Spirillum*, on the other hand, exhibited a most extraordinary susceptibility to immersion in water, for in none of these waters could its presence be demonstrated after the first day.

The results obtained with Koch's *Spirillum of Asiatic cholera* were particularly instructive, for when this was taken from a weak culture in gelatine, the spirilla were no longer demonstrable after the first day in the infected waters, but when the spirilla of the same cultivation were revivified by cultivation in broth and then introduced into the aqueous media they were found to multiply abundantly in the sewage, whilst in the deep-well and filtered Thames water they underwent numerical reduction in the first instance, followed by slight multiplication, which was again succeeded by decline, and on the ninth day they were still demonstrable. A temperature of 35° C. caused their more rapid destruction, as confirmed by the results of other investigators.

In a later paper by one of us† the author finds that the *cholera spirilla* have remained alive for eleven months in the sterile sewage, and in further experiments with *Bacillus anthracis*, he found that in sterile distilled and in sterile filtered Thames water the organisms remained alive for upwards of sixty days, a considerable diminution taking place during the first days, after which the numbers remained practically constant. The initial diminution, he suggests, is due to the dying off of the bacilli, the spores alone surviving. In sterile London sewage *Bacillus anthracis* underwent considerable multiplication. Experiments were also made with the *Streptococcus of erysipelas* (Fehleisen), which was apparently destroyed within one hour in distilled water, but lived from two to five days in sterile filtered Thames water, and two days in sterile London sewage.

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* These results are partly in accordance with, and partly contradictory of, Miquel's observation that the action of numerous Schizomycetes in a water may render that water "immune" to infection by other Schizomycetes, as quoted in the footnote to p. 203.

† Percy F. Frankland, "Recent Bacteriological Research in connection with Water Supply," 'Journ. Soc. Chem. Industry,' 1887.

Kraus contributed a valuable paper in 1887.[*] After pointing out that, important as are the results of Meade Bolton, and of Wolffhügel and Riedel, to science, they have very little practical utility, because (1) they concern chiefly sterilised waters, which do not occur in the open, and (2) the temperatures employed were too high to be compared with what happens in daily life, this author proceeds to describe his results with ordinary drinking waters kept at about 10·5° C.

He found that the typhoid bacillus under these circumstances soon succumbs to the rapidly increasing "water forms," and that it was eliminated in seven days.

Koch's cholera spirillum could not hold its ground more than two days at this temperature, in contest with the rapidly dominating aquatic forms.[†]

Even *Bacillus anthracis* disappeared from these waters in four days.

Kraus concludes that much more must be put down to the direct effect of the competing bacteria in such cases, than to the quality of the water or the original number of forms contained in it.

We may remark in this connexion that it bears out what is also deducible from the preceding results of Bolton and Wolffhügel and Riedel,[‡] and further, that this view of Kraus is distinctly supported by our knowledge of the competing action of dominant forms, due to their successful seizure of oxygen, food materials, &c., on the one hand, and to the toxic actions of their metabolites on the other.[§] It is not improbable that sterilisation by heat acts both by setting free food materials in the form of dead bacteria, as well as by destroying such toxic principles.

Gärtner[||] found that typhus bacilli will *live* for long periods in waters, but concluded that it does *not multiply* in them unless appreciable quantities of organic food materials are present: he found that $\frac{1}{400}$th part of bouillon added to the water induced vigorous growth and multiplication.

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[*] "Ueber das Verhalten pathogener Bacterien im Trinkwasser" ('Arch. f. Hyg.,' vol. 7, 1887, p. 234).

[†] These and similar results with mixtures of microbes must be received with great caution, as already pointed out, for it has been proved by Gruber ('Wiener Mediz. Wochensch.,' 1887, Nos. 7 and 8) that on placing the cholera spirilla in contact with ordinary putrefaction bacteria, the latter, in the first instance, gain an enormous numerical ascendency over the cholera spirilla; but if the struggle between the two be sufficiently protracted, the cholera spirilla can, at the close of the putrefaction process, be still found in the living state.

[‡] Bolton, however, made no experiments with unsterile water; and Wolffhügel is far from convinced as to the *destruction* of typhoid bacilli by water bacteria, putting down their absence on the plate cultures rather to experimental difficulties of finding them. It is not impossible that the experimental difficulties account for these results of Kraus.

[§] See also note on p. 203 regarding Garré and Miquel's results.

[||] "Pathogene und Saprophytische Bakterien in ihrem Verhältniss zum Wasser, insbesondere zum Trinkwasser" ('Correspondenz-Blätter des allgem. Aerztl. Vereins von Thüringen,' 1888, Nos. 2 and 3).

He concludes that cholera germs cannot multiply in ordinary waters, under ordinary conditions; but the temperature, the nature of the competing bacteria, and the vitality of the cholera germs themselves affect the question.

Among other factors which influence the life of microbes in water, carbon dioxide may be assumed to be of importance: most forms are influenced more or less adversely, whilst perhaps some are not susceptible to its presence.* Light is of no consequence in this respect.

Ferrari, in a paper dealing with the effect of various fluids employed in surgery on pathogenic organisms, observed that *Staphylococcus pyogenes aureus* rapidly multiplies in distilled water,† and this to such an extent that the effects were observable during several days, and the numbers were so large by the fifth day that they could no longer be estimated.

At the same time, the preliminary diminution of numbers during the first hours or days in these cases (and in similar experiments of numerous other observers already referred to) suggests the suspicion that some of the increase at least must be attributed to the decomposition of those which die when first put into the water. Braem has shown pretty clearly that in some cases, at any rate,* distilled water kills anthrax and cholera bacilli, as well as *Staphylococcus pyogenes aureus*, though not always rapidly. Thus cholera lived for 24 hours, anthrax from 8 to 12 days, while the *Staphylococcus* required 25 to 50 days for its elimination.

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* Kolbe ('Journ. f. Praktische Chemie,' N.F., 1882, vol. 26, and 1886, vol. 28) had already pointed out the antiseptic action of carbonic anhydride, in connexion with the preservation of beef, and Leone (*loc. cit.*) showed how the number of microbes in water underwent rapid diminution on saturating the latter with carbonic anhydride at ordinary pressures; although the complete destruction of germs cannot be relied on by this agency, it points, at any rate, to the greater safety of carbonated waters, more especially if they have been kept for some time in stock. Systematic experiments have also been made on the action of carbonic anhydride on specific micro-organisms, pathogenic and harmless, by C. Fraenkel (" Einwirkung der Kohlensäure auf die Lebensthätigkeit der Mikro-organismen," 'Zeitschr. f. Hyg.,' vol. 5, 1889, p. 332), and by one of us (Percy F. Frankland, " On the Influence of Carbonic Anhydride and other Gases on the Development of Micro-organisms," 'Roy. Soc. Proc.,' vol. 45, 1888, p. 292, 'Zeitschr. f. Hyg.,' vol. 6, p. 13). These investigations show that by far the greater number of known bacteria, both pathogenic and otherwise, have their growth arrested by carbonic anhydride, although many of them subsequently revive on exposure to air. The most important papers on the effect of this gas, in mineral waters, on bacteria are Hochstetter ("Ueber Mikro-organismen im künstlichen Selterwasser nebst einigen vergl. Unters. ü. ihr Verhalten im Berl. Leitungswasser u. im dest. Wasser," 'Arb. a. d. Kais. Gesundheitsamte,' vol. 2, 1887, H. 1 and 2); Reinl (" Die gebräuchlichsten kohlensäurehaltigen Luxus- und Mineral-Wässer vom bakteriol. Standpunkte," 'Wiener Med. Wochenschr.,' 1888, Nos. 22 and 23); Fazio ('I Microbi delle Acque Minerali,' Naples, 1888).

† "Ueber das Verhalten von Pathogenen Mikroorganismen in den subcutan einzuspritzenden Flüssigkeiten" ('Centr. f. Bakt.,' vol. 4, 1888, p. 744). It should be pointed out that in this respect his results are in direct antagonism to Meade Bolton's with the same organism.

Braem says that the typhoid bacilli were still active after 60 days in distilled water, and were not eliminated till 188 days had passed.

In the present state of our knowledge such results can most reasonably be explained on one of the three following assumptions:—(1) Either the distilled water was not pure (*i.e.*, it was contaminated in the still, or more probably by food materials carried in during infection); or (2) the products of decomposition of the dead and dying bacteria during the sojourn in the water, afforded food materials for the rest. Most probably both sources of error occur in those cases where the increase is very marked and prolonged: of course the products of decomposition of previously living bacteria would only account for a smaller number than the original, *i.e.*, the usual case. Whilst (3) the possibility may be suggested, that the progeny formed in the distilled water is of a degraded order, in which the individuals have a smaller dry body weight than the original forms introduced.

Uffelmann,† experimenting with the waters of Rostock, finds that typhoid bacilli, at ordinary temperatures, can hold their own for from several days to two weeks; and that *Bacillus anthracis* remained alive for three months. Although cholera germs are much less resistant, yet they, also, may be carried in such waters as are used for domestic purposes.

Karlinski‡ investigated the bacteria of five Innsbruck waters, and then determined their normal behaviour at 8° C.: in all, the numbers of Schizomycetes increased when the water was allowed to stand at this temperature. He then infected these waters with the bacilli of typhoid, cholera, and anthrax, and kept them also at 8° C., and found that these all diminished rapidly in numbers in the struggle with the increasing and eventually dominant water forms. Cholera could not maintain itself for three days, typhoid not beyond six days, and anthrax three days at the given temperature. It will be noticed that this is a valuable confirmation of Kraus's results at 10·5° C.

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* "Recherches sur les Phénomènes de Dégénérescence des Bactéries Pathogènes dans l'Eau Destillée" (Ziegler's 'Beitr. zur Pathol. Anat.,' vol. 7, H. 1).

† "Trinkwasser und Infections-krankheiten" ('Wiener Medicinische Presse,' 1888, No. 37).

‡ "Ueber das Verhalten einiger pathogener Bakterien im Trinkwasser" ('Arch. f. Hyg.,' vol. 9, 1889, p. 113).

In a second paper,* Karlinski goes more deeply into the question of the maintenance of the typhoid bacillus in a natural water, working in the open in order to avoid the errors due to confined samples in the laboratory. The temperature, chemical constitution, and bacterial contents of the water were examined, and the well was then infected with a bouillon culture of typhoid germs.

Daily examination of the contents, continually stirred to prevent precipitation, showed a rapid increase of the normal water bacteria, and a corresponding decrease of the typhoid bacilli, till none of the latter remained after fourteen days.

The chemical constitution of the water, examined daily, also restored itself during the fourteen days through which the infection lasted. Other experiments confirmed these results.

§ IV. *Summary and Conclusions.*

If we now try to put together the results of the various investigations referred to, it is evident that the inquiry into the vitality of micro-organisms in ordinary waters is by no means to be carried out merely by putting such germs into a given water, leaving them there for a time, and simply determining their relative increase or decrease during a given period.

The first fact to be firmly grasped is that water, as met with in actual life, is a very variable medium indeed; and that even when it is admitted that such rough distinctions as are implied by the names river water, spring and well water, distilled water, soft and hard water, and so on, classify the subject but imperfectly, the matter is by no means ended. Not only are no two river waters alike in constitution, but probably no two samples of distilled water are absolutely so when the original water has been taken from different sources in the first instance.

The second great fact to be clearly apprehended is that a Schizomycete is not only a very minute organism, but that it requires correspondingly minute traces of food materials for its nutrition: consequently there is less cause for surprise than is sometimes expressed at the existence of such large numbers of these micro-organisms in a natural water which has passed over the soil in contact with the atmosphere, and attained an ordinary temperature.

A less obvious truth—but one that must be insisted upon—is that a Schizomycete is an extremely delicate organism, simply because it is a living being, and therefore its reactions to a medium such as an ordinary water are far more delicate and complex than those of the usual chemical reagents: furthermore, and this is one of the most important points of all, the living Schizomycete is a variable factor in itself, because it has a variable organisation.* When, therefore, we place bacteria in water, we must not expect the resulting reactions to be constant.

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* "Ueber das Verhalten des Typhus-bacillus im Brunnenwasser" ('Arch. f. Hyg.,' vol. 9, 1889, p. 432).

The matter is obviously rendered still more complex when we turn a given species of Schizomycete into a water already peopled with aquatic (and, therefore, presumably well adapted) forms of different species; for the whole teaching of biology shows that the competing organisms cannot exist side by side without affecting the welfare of each.

If we assume the simplest case, for the sake of argument, we have to remember at least the following:—

(1.) The water itself affects the living speck of protoplasm we place in it, not only mechanically, but more especially physically and chemically.†

(2.) The gases dissolved in the water exert pronounced effects, as is known from the relations of oxygen and carbon dioxide to plant life in general, and from the effects of these and various other gases on bacteria in particular.

(3.) Any dissolved or suspended substances in the water must exert definite actions on the living organism. This applies not only to the minerals and organic substances in solution which are directly useful as food materials, but also to products of metabolism or of other chemical changes which are injurious to the life of the protoplasm of the microbe. Moreover, it applies to suspended particles which exert surface attractions towards the suspended micro-organisms,‡ or which affect the water in any way.

(4.) The temperature of the water is, as has been seen, of the utmost importance for the life or otherwise of any given species; and it requires but a moment's consideration to see that this factor exerts an important influence on all the preceding.

(5.) Although we are still very ignorant of the relations of light to this subject, it is at any rate clear that in some cases at least certain rays of light may complicate matters when they fall in sufficient quantity on water containing bacteria in suspension, and organic substances in solution, but it is not probable that this forms an important factor in the case of natural waters which cannot be subjected in their entirety to direct insolation.

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* Proofs of this will suggest themselves to every biologist. We need simply refer to Roux's experiments with anthrax ('Ann. de l'Inst. Pasteur,' 1887, p. 392), and to those of Wolffhügel and Riedel ('Arb. a. d. Kais. Gesundheitsamte,' 1886, p. 455) with cholera.

† As regards this we may call attention to the plasmolysis experiments of De Vries, Pfeffer, Fischer, and Wladimiroff already referred to on p. 198.

‡ There is a large literature on this subject (and the allied one of filtration). See Percy F. Frankland ("The Removal of Micro-organisms from Water," 'Roy. Soc. Proc.,' 1885, pp. 379—393), and Krüger ("Physikalische Einw. v. Sinkstoffen auf die im Wasser befindl. M'organismen," 'Zeit. f. Hyg.,' vol. 7, 1889, pp. 86—114); also Duclaux ("Le Filtrage des Eaux," 'Ann. de l'Inst. Past.,' 1890, pp. 41—46), where other references are given.

(6.) The evidence is still less conclusive as regards mechanical disturbances in the water, so far as they directly affect the living cells of the micro-organisms, but it is at least highly probable that every wind-raised wave, every tumble over a fall or weir, and every pause in a backwater or lake, must affect the matter, if only in so far as it alters the gaseous contents of the water, or the relative distances between the individual micro-organisms.

Enough has been said to show that the bacteriologist who attacks the question before us must at least bear these facts in mind.*

Now, as to the questions of distilled as opposed to non-distilled water, and of sterilised as opposed to non-sterile waters.

It will be conceded forthwith that distilled, and we will assume pure, water offers little scope for practical enquiry. Such water is unknown in nature, except momentarily or in inaccessible forms, and the only lessons to be expected from its action on bacteria are of purely scientific and philosophical interest; distilled water, therefore, should be used in check experiments, and the results compared with those obtained with other waters, not forgetting that "distilled water" is not a constant medium.

As to experiments with sterilised water, the matter is very different, for most observers are unanimous as to the longer vitality of pathogenic forms in sterilised water than in the same water before sterilisation; the experiments in sterilised water may thus furnish us with the ultimate limits of vitality, and will, therefore, act as valuable guides.

It must, however, be remembered that there are two ways of sterilising a water,† (1) by heat and (2) by filtration. In both cases the constitution of the water may be altered. Where heat is employed the gases are driven off, in whole or in part; soluble products may be rendered insoluble, *e.g.*, carbonates precipitated; the proteids, &c., of the killed micro-organisms are placed more or less at the disposal of the living ones which follow; and the solution (which a natural water really is) becomes more concentrated.‡ Moreover, many metabolites of the nature of ptomaines and the like must be altered or destroyed.

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* We have not thought it necessary to discuss the question as to the action of electricity on bacteria: the results hitherto are negative, excepting in so far as electrical currents alter the chemical constitution of the medium. For literature and criticism see Duclaux ("Action de l'Électricité sur les Microbes," 'Ann. de l'Inst. Past.,' vol. 4, 1890, pp. 677—680).

† It is obviously unnecessary to discuss sterilisation by means of antiseptic and poisonous substances, although this is, of course, of great importance in connexion with the treatment of sewage, &c.

‡ Though, of course, there is not *necessarily* diminution in volume in the process of sterilisation.

Filtration, through porous films of porcelain, certainly acts less violently on the water; but it must by no means be concluded that either the chemical constitution or the physical character of such filtered water is absolutely unaltered. In the case of ordinary filtration one series of changes alone, viz., the alteration of the proportions of the gaseous contents owing to the difference of pressure on the two sides of the filtering film, will illustrate this.*

On the whole, however, we may conclude that in cases where it is necessary to eliminate the living bacteria of a natural water, the process of filtration through porous porcelain is a better method than that of sterilisation by heat.

There can be little doubt that some of the discrepancies between the results of the various observers, referred to on pp. 204—214, are chiefly due to the sources of difference here indicated.

It may be concluded, with some show of certainty: (1) That the numerical results obtained by the gelatine-plate method, are, on the average, too low.

(2.) That several workers employed temperatures too high for comparison with what occurs in natural waters in this country.

(3.) That many of the results are vitiated by small quantities of very concentrated food materials having been introduced into the waters with the pathogenic germs employed for infection.

(4.) That the conclusions drawn from experiments with distilled water must be received with great caution, and are of little practical value. On the whole we may regard "pure" water as a worse medium for the life of pathogenic bacteria,† in spite of apparently contradictory results in the hands of some of the investigators.

(5.) That the conclusions drawn from cultures in sterile waters must also be received with due regard to all the facts, and especially those where the water was sterilised by heat.

On the other hand, the enormously greater experimental difficulties attending the investigations in which unsterilised waters are used necessitate that the results should also be very carefully scrutinised, and should not be finally accepted until confirmed by numerous investigators attacking the question from different points of view, and using different methods of research.

(6.) That it is not safe to regard mineral waters as necessarily free from pathogenic germs capable of living, any more than it is to suppose that water in the form of ice, snow, hail, or rain is incapable of conveying infection during times of epidemics; and that, in point of fact, *any* water whatever may convey living pathogenic germs from one place to another.

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* For the effect of filtration through porous porcelain on the chemical composition of water, see Percy F. Frankland ("The Removal of Micro-organisms from Water," 'Roy. Soc. Proc.,' 1885).

† It may be remarked that the pathogenic bacteria, from the nature of the case, are less adapted for life in media poor in organic materials than are the saprophytic forms, and especially those known as "aquatic."

(7.) That the periods through which pathogenic bacteria can live in water vary according to a long series of circumstances, depending especially on the nature and vigour of the germs, whether they form spores or not, the chemical and bacteriological nature of the contents of the water, the mode of contamination, and the temperature.

(8.) That in all ordinary waters the rule is that the pathogenic forms die out sooner or later, with or without previous temporary multiplication; very commonly this final result is reached in three stages: (*a*) a preliminary diminution, due to the death of large numbers occasioned by the shocks induced by their altered environment; (*b*) a longer or shorter period of more or less active growth and multiplication; and (*c*) gradual diminution in numbers and vigour, as the available food materials become exhausted.

(9.) As regards specific forms of pathogenic bacteria, existing information extends chiefly to the following:—*

Spirillum choleræ asiaticæ has been shown to live, and even multiply, in drinking waters, though the results as to time are very conflicting; whereas some found it dead after a couple of days, others state that it lives a year† in such waters. It is impossible to reconcile all the statements; the only points of general agreement seem to be that cholera *can* be conveyed by water, and that it is, as a rule, not very resistant towards the competing forms.

Bacillus typhosus.—This seems to be much more resistant than the cholera spirillum in most cases. Meade Bolton pointed out that it needs far less organic material than cholera for its successful propagation in water. The results of several observers point to its being able to retain its powers for at least three months in drinking or river waters; but it seems to be eliminated more rapidly at higher temperatures (above 18—20° C.) than at moderately low (8—12° C.) ones. It may certainly be regarded as more able to hold its own against the resident forms in bad waters than is the cholera spirillum, and some results even suggest that the presence of other forms favours it (Hueppe, Hochstetter). Karlinski's and Holz's researches, however, are decidedly opposed to this.‡

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* See Appendix C for tabulated results.

† Wolffhügel and Riedel found the cholera bacillus alive in some cases after from seven months to a year. Hochstetter gives 267—392 days. Pfeiffer has similar results.

‡ See especially "Unters. über das Verhalten der Typhus-bacillen in typhösen Dejektionen" ('Cent. f. Bakt.,' 1889, vol. 6, p. 65, and especially p. 75), and Max

Bacillus anthracis.—The vegetative rodlets of this form are invariably found to be less able to hold their own than the spores, a result quite intelligible from what is known of this well-studied Schizomycete. All agree as to the general fact that the spores of anthrax may live in sterile water for months without injury, provided the temperature is not too high.

The *Streptococcus of erysipelas* appears to be remarkably susceptible to immersion in water; it was found to be almost immediately destroyed in distilled water, and survived only five days in sterile sewage and drinking water.

Micrococcus tetragenus, according to Straus and Dubarry, can maintain itself for 18—30 days in various waters, whilst Meade Bolton gives it a much shorter lease of life.

Bacillus tuberculosis lived for more than 115 days in distilled water, and 95 in river water, according to Straus and Dubarry. Cornil* kept it alive in Seine water for 70 days.

Staphylococcus pyogenes aureus is said to live for more than 19 days in river water (Straus and Dubarry).

The same observers give more than 50 days for the bacillus of glanders, 30 days for the micrococcus of fowl-cholera, 17 days for the bacillus of swine-plague, and 20 days for that of mouse-septicæmia. Ferrari† found this form alive for several weeks in distilled water.

APPENDIX A.

The Literature which concerns the several Questions treated of in this Report.

We have added a short note on the scope and importance of some of the works, so far as it appears useful to do so; at the same time, it should be borne in mind that the relative value of any particular paper may depend on many circumstances incidental to the particular purpose the reader has in view, and our opinion is only intended to express what we regard as the chief feature of the work from the points of view in this Report.

Holz, "Exp. Unters. über den Nachweis der Typhus-bacillen" ('Zeitsch. f. Hyg.,' vol. 8, 1890, p. 143).

* Quoted by Woodhead, 'Bacteria and their Products,' p. 211.

"Ueber das Verhalten von pathogen. Mikroorg., &c." ('Centralbl. f. Bakt.,' 1888, vol. 4, p. 744).

I *Literature dealing more especially with Bacteriology in general.*

GENERAL TREATISES.

Baumgarten. Lehrbuch der pathologischen Mykologie. Brunswick, 1886–90.

A treatise on the relations of micro-organisms to disease.

Cornil and Babes. Les Bactéries. Paris, 1890.

Pathological.

Crookshank. Manual of Bacteriology. 3rd ed. London.

Chiefly pathological.

De Bary. Comp. Morph. and Biology of Fungi, &c. Oxford, 1887.

Botanical.

—— Lectures on Bacteria. 2nd ed. Oxford, 1887.

Botanical. An excellent popular *résumé* of the subject.

Eisenberg. Bakteriologische Diagnostik. Leipzig, 1891.

A technical treatise designed to facilitate the recognition of the forms observed.

Flügge. Die Mikroorganismen. Leipzig, 1886. Engl. ed. London, 1890.

A concise, yet comprehensive, standard treatise for the recognition of forms, especially pathological.

Fraenkel. Text Book of Bacteriology. (Tr. Lindsley.) New York. Wood and Co.

An excellent general treatise in small compass.

Hueppe. Die Methoden der Bakterien-Forschung. Ed. 1892.

A generally-acknowledged authority on methods.

Macé. Traité pratique de Bactériologie. 1892.

A useful treatise.

Miquel. Manuel pratique d'Analyse Bact. des Eaux. Gauthier-Villars. Paris, 1891.

A work mainly advocating the dilution method of culture, and full of excellent hints.

Saccardo. Sylloge Fungorum. Vol. 8. 1889.

The standard work on the systematic classification.

Marshall Ward. The article "*Schizomycetes*" in Encyclopædia Britannica. 9th ed.

A summary of the morphology and physiology of forms, and of the general aspects of bacteriology.

Woodhead. Bacteria and their Products. London, 1891.

Résumé.

Zopf. Die Spaltpilze. 3rd ed. Breslau, 1885.

The best text-book from the point of view of polymorphy.

FOR BACTERIOLOGICAL METHODS SEE ALSO:—

Bolkin. Isolirung anaërober Bakterien. Chem. Centr. 1891. Vol. 1. No. 4.
Technical.

Brefeld. Methoden zur Unters. der Pilze. Abh. der Phys. Med. Gesell. in Würzburg. 1874.

—— Landwirthsch. Jahrb. Vol. 4. H. 1.

—— Unters. über Schimmelpilze. H. 4. 1881.
Purely technical.

Esmarch. Ueber eine Modification des Koch'schen Plattenverfahrens. Zeitsch. f. Hygiene. Vol. 1. P. 293.
Important addition to bacteriological methods.

Koch. Method of Gelatine Plate Culture. Quart. Journ. Micr. Sci. October, 1881.
Résumé.

—— Zur Untersuchung von pathogenen Organismen. Mitth. aus d. K. Gesundheitsamte. Vol. 1. Berlin, 1881. Pp. 1–48.
The classical paper on the subject of cultures on solid media.

—— Berl. Klin. Wochenschr. 1882. No. 15.
Résumé.

Petri. Kleine Modification des Koch'schen Plattenverfahrens. Centralb. f. Bakt. Vol. 1. P. 279.
A note.

Sell. Ueber Wasseranalyse unter besonderer Berücksichtigung der im Kais. Gesundh'amte üblichen Methoden. Mitth. K. Ges'amte, Berlin. Vol. 1. 1881. Pp. 360–77.
Technical.

2. *Literature dealing specially with the Bacteria of Water.*

Adametz (L.) Die Bakterien der Trink- und Nutzwässer. Mittheil. d. Österr. Versuchsstat. f. Brauerei u. Malzerei Wien. H. 1. 1888.
Technical.

—— Unters. ü. *Bacillus lactis viscosus*, &c. Berl. Landwirths. Jahrb. 1891. Centralb. f. Bakt. Vol. 9. P. 698.
Special.

Ali-Cohen. Eigenbewegung bei Mikrokokken. Centralb. f. Bakt., &c. Vol. 6. 1889. P. 34.
Deals particularly with the question of cilia.

Aradas. Esame batterioscopico dell' Acqua della Reitana, &c. Atti Accad. Gioenia, Catania. Ser. III. Vol. 20. Pp. 1–11.

Technical.

Billet. Contrib. à l'Étude de la Morph. et du Développement des Bactériacées. Paris, 1890.

Contains full literature and numerous morphological facts; records the discovery of endospores in *Cladothrix*.

Bokorny. Ueber den Bakteriengehalt der öffentlichen Brunnen in Kaiserslautern. Arch. f. Hyg. Vol. 8. 1888. Pp. 105–110.

Technical.

Boutroux. Revue des Travaux sur les Bactéries, &c. Rev. Générale de Bot. 1890. Vol. 2.

Résumé.

Brödtler. Sur la Biologie des Germes vivants dans l'Eau. Berlin, 1888.

General.

Bujwid. Wyrniki bakt. badan wody Warszaw, &c. Zorowie, 1889. Centralb. f. Bakt. 1890. Vol. 8. P. 395.

Claessen. Ueber einen Indigo-blauen Farbstoff erzeugenden Bacillus aus Wasser. Centralb. f. Bakt. Vol. 7. 1890. Pp. 13–17.

Special.

Cramer. Die Wasserversorgung von Zürich. 1884 and 1885.

An important contribution.

Despeignes. Étude expérimentale sur les Microbes des Eaux, &c. Paris, 1891. Centralb. f. Bakt. Vol. 10. P. 563.

Special.

Duclaux. Les Microbes des Eaux. Ann. Inst. Past. Vol. 3. 1889. Pp. 559–569.

An excellent critical review of the whole subject.

Emmerich. Das Brunnenwasser von Lissabon. Arch. f. Hyg. Vol. 1. 1883. Pp. 389–396.

Technical.

Erismann. Handbuch d. Hygiene. Vol. 2. Abth. 2. P. 214.

The book is a general one. We quote a reference to water bacteria.

Fol & Dunant. Arch. des Sci. phys. et nat., Genève. 1884, 1885.

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Fränkel (C.) Untersuchungen über Brunnendesinfection und den Keimgehalt des Grundwassers. Zeitschr. f. Hyg. Vol. 6. 1889. Pp. 23–61.

A valuable contribution to the subject of the contamination of well-waters.

Fränkel. Grundwasser und Bakterien. Deutsch. Med. Zeits. 1889. No. 17. Centralb. f. Bakt. Vol. 5. P. 640.
Résumé.

Frankland (Grace and P. F.) Ueber einige typische Mikroorganismen im Wasser und im Boden. Zeitschr. f. Hyg. Vol. 6. 1889. Pp. 373–400.
Deals with and figures several forms in detail.

Frankland (P. F.) Micro-organisms in London Water Supply; Monthly Reports of Official Water Examiner to Local Government Board, 1885–88.
Statistical account of numbers revealed by gelatine cultivation.

—— The Hygienic Value of the Bacteriological Examination of Water. Internat. Congr. of Hygiene and Demogr. 1891.

Gärtner. Unters. des Wassers. P. 581.

Gunning. Beitr. z. hygienischen Unters. des Wassers. Arch. f. Hyg. Vol. 1. 1883. Pp. 335–351.
Technical.

Hansen. Methode zur Analyse des Brauwassers in Rücksicht auf Mikro-organismen. Zeit. f. d. Ges. Brauwesen. 1888. No. 1. Centralb. f. Bakt. Vol. 3. P. 377.
Deals especially with brewing waters.

Hansgirg. Ueber die Bakteriaceen-Gattung Phragmidothrix, &c. Bot. Zeit. 1891. Col. 313–315.
Morphological.

Haudring. Bakteriologische Untersuchungen einiger Gebrauchswässer Dorpats. Dorpat, 1888. Centralb. f. Bakt. Vol. 5. P. 485.
Technical.

Heinz. Bakteriolozka analiza Zagrebačkih pitka voda. Soc. Hist. Nat. Croatica. Vol. 3. 1888. Pp. 286–324. Centralb. f. Bakt. Vol. 5. P. 641.

Hueppe. Journ. f. Gasbeleucht. u. Wasserversorg. 1887–88.
One of the most valuable critical papers on the subject.

Jolles. Gutachten über ein behufs chem. und bakt. Unters., &c., Wasser. Zeitschr. f. Nahrungsmittel-Unters. u. Hyg. January, 1890. Centralb. f. Bakt. Vol. 8. P. 398.

Koch. Die Bekämpfung der Infectionskrankheiten. Rede zur Stiftungsfeier der Militärärztlichen Bildungsanstalten. 1888. P. 25.
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Leone. Recherches sur les Micro-organismes de l'Eau Potable. Atti d. R. Accad. Lincei, Rome. Serie IV. Vol. 1.

Technical.

Lustig. Ein rother Bacillus im Flusswasser. Centralb. f. Bakt. Vol. 8. P. 33. 1890.

Deals with the question of action of light.

—— Diagnostica dei Batteri delle Acque, &c. Torino, 1890. Centralb. f. Bakt. Vol. 8. P. 594.

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Macé. Sur quelques Bactéries des Eaux de Boisson. Ann. d'Hygiène Publique et de Méd. Légale. Vol. 17. 1887. No. 4. Centralb. f. Bakt. Vol. 3. P. 143.

Technical.

—— Sur les Caractères des Cultures du *Cladothrix dichotoma* (Cohn). Comptes Rendus. Vol. 106. 1888. P. 1622. Centralb. f. Bakt. Vol. 4. P. 199.

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Maggi. Eaux Potables considérées comme Boisson de l'Homme et des Animaux. Milan, 1884.

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Malapert-Neufville. Examen Bactériologique des Eaux Naturelles. Annales d'Hygiène Publique et de Méd. Légale. Vol. 17. Pp. 193-247. Centralb. f. Bakt. Vol. 3. P. 7.

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E. Meyer. Bacteriological Water-Tests, 1886.

Michael. Typhus-bacillen im Trinkwasser. Fortschritte d. Medicin. 1886. Vol. 4. P. 353.

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Miquel. Annuaires de l'Observatoire de Montsouris. 1879 and following years.

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Mörs. Die Brunnen der Stadt Mülheim, &c. Ergänzungs-Hefte z. Centralb. für allg. Gesundheitspflege. 1886. Vol. 2. P. 144.

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Important.

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Sirena. Sulla Resistenza Vitale del Bacille Virgola nelle Acque. Riforma Medica. 1890. No. 14. Centralb. f. Bakt. Vol. 8. P. 268.

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Wolffhügel & Riedel. Die Vermehrung der Bakterien im Wasser. Arbeiten a. d. Kais. Gesundheitsamte. Vol. 1. Berlin, 1886. Pp. 455–480.
A very valuable contribution, full of suggestions and facts.

We now append Lists (Appendix B) of all the species of Schizomycetes detected in various kinds of waters, so far as we have been able to get at the records.

The question of synonymy is, in the present state of bacteriology, a very difficult one; we have, in most cases, placed the best known name first, but those who prefer to adopt other names may be referred to Saccardo's 'Sylloge Fungorum,' vol. 8, 1890, for the synonyms and descriptions of most of the species. Some of those recorded here are new, having been published since the above work appeared; in the case of these forms, the descriptions will be found in the memoirs quoted.

APPENDIX B.—Schizomycetes found in Drinking Water.

Species.	Synonyms.	Authorities for habitat.	Remarks.
Micrococcus aërogenes (Miller)	..	Tils, 'Zeit. f. Hyg.,' 1890, p. 282	In alimentary canal
M. agilis (All-Coh.)	*Neisseria agilis* (Trev.)	Ali-Cohen, in 'Centralb. f. Bakt.,' 1889, vol. 6, p. 36, and Podrowsky, *idem*, vol. 10, p. 566	
M. aquatilis (Bolt)	..	Meade Bolton, in 'Zeitschr. f. Hyg.,' 1886, p. 94	Very common in water
M. aurantiacus (Cohn)	*Pediococcus aurantiacus* (Trev.), *Bacteridium aurantiacum* (Schröt.)	Adametz, 'Die Bakt. des Nutz- u. Trinkwassers,' Wien, 1888; Podrowsky, 'Cent. f. Bakt.,' vol. 10, p. 566; Migula, in 'Cent. f. Bakt.,' vol. 8, 1890, p. 357; and Tils, 'Zeitschr. f. Hyg.,' 1890, p. 282	Common in soil and decomposition and in water
M. candicans (Fl.)	? not *Neisseria Franklandiorum*	Migula, *loc. cit.*, and Tils, 'Zeit. f. Hyg.,' 1890, p. 282	Common in atmospheric dust, &c.
M. candidus (Cohn)	..	Tils, *loc. cit.*	Also on potatoes
M. carneus (Zimm.)	..	Zimmermann, *loc. cit.*	
M. cerasinus siccus (List.)	..	G. Roux, 'Analyse Microbiologique de l'Eau,' Paris, 1892, p. 285	
M. cereus albus (Schröt.)	*Staphylococcus cereus* (Trev.), *St. cereus albus* (Passet)	Tils, *loc. cit.*	In pus, not pathogenic
M. cinnabareus (Fl.)	*Streptococcus cinnabareus* (Fl.)	Migula, *loc. cit.*, and Podrowsky, *loc. cit.*	Was not found in clear mountain or running streams
M. citreus (List.)	..	Roux, *loc. cit.*, p. 285	
M. concentricus (Zimm.)	..	Zimmermann, "Die Bakterien unserer Trink- u. Nutzwässer," in 11th 'Ber. der Naturw. Gesell. zu Chemnitz,' 1890	

M. coronatus (Fl.)	*Streptococcus coronatus* (Fl.)	Migula, *loc. cit.*	Also in air
M. cremoides (Zimm.)	..	Zimmermann, *loc. cit.*	
M. cyaneus (Schröt.)	*Bacteridium cyaneum* (Schröt.)	Roux, *loc. cit.*, p. 287	Also on potatoes
M. fervitosus (Adam.)	..	Adametz and Wichmann, in 'Mitth. Oesterr. Vers.-Stat. f. Brauerei,' &c., Wien, 1888, p. 29, and Tils, *loc. cit.*	Common in water
M. fulvus (Cohn)	*Staphylococcus fulvus* (Cohn)	Roux, *loc. cit.*, p. 287	Ordinary habitat horse-dung
M. flavus desidens (Fl.)	*Streptococcus desidens* (Trev.)	Adametz, Migula and Tils, *loc. cit.*	Common in cultures and air
M. flavus liquefaciens (Fl.)	*M. flavus* (Trev.)	Migula and Tils, *loc. cit.*; also Podrowsky, 'Cent. f. Bakt.,' vol. 10, p. 566	Occasional
M. flavus tardigradus (Fl.)	*M. tardigradus* (Trev.)	Migula, *loc. cit.*	Occasional
M. fuscus (Masch.)	..	G. Roux, 'Anal. microbiol. des Eaux,' p. 280	Probably identical with *Bacillus prodigiosus*, *q.v.*
M. luteus (Cohn)	*Bacteridium luteum* (Schröt.)	Migula and Tils, *loc. cit.*, and Adametz, 'Unters. über die niederen Pilze,' &c., 1887, p. 9	Common in soil
M. plumosus (Braüt.)	..	Eisenberg, *loc. cit.*, p. 56; Roux, *loc. cit.*, p. 292	
M. prodigiosus (Ehrenb.)	(See *Bacillus*)	Roux, *loc. cit.*, p. 281	
M. radiatus (Fl.)	*Streptococcus radiatus* (Fl.)	Adametz, Migula, *loc. cit.*, and Karlinski, 'Arch. f. Hyg.,' 1889, p. 113	Occasional in cultures
M. rosettaceus (Zimm.)	..	Zimmermann, *loc. cit.*	
M. ureæ (Cohn)	*Streptococcus ureæ* (Fl.), '*Torule ammoniacale*" (Pasteur)	Migula and Tils, *loc. cit.*	Common in urine and in all waters contaminated by it
M. versicolor (Fl.)	..	Migula and Tils, *loc. cit.*	One of the commonest species in soil, air, and water, even on mountains
M. violaceus (Cohn)	*Streptococcus violaceus* (Cohn), *Bacteridium violaceum* (Schröt.), *Chromococcus violaceus* (Berg.)	Roux, *loc. cit.*, p. 289, and Eisenberg, *loc. cit.*, p. 42	Found also on potatoes
M. viticulosus (Fl.)	..	Migula and Karlinski, *loc. cit.*	
Diplococcus luteus (Adam.)	*Neisseria lutea* (Adam.)	Tils, *loc. cit.*	Soil and water

Schizomycetes found in Drinking Water—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
Streptococcus albus (Masch.)	..	Roux, *loc. cit.*, p. 283	
St. vermiformis (Masch.)	..	Roux, *loc. cit.*, p. 284	
Sarcina alba (Eisenb.)	..	Roux, *loc. cit.*, p. 295	Common also on skin and in air
S. aurantiaca (Fl.)	..	Migula, *loc. cit.*	In air also
S. candida (Lindn.)	..	Lindner, *loc. cit.*	Brewery waters and air
S. lutea (Fl.)	..	Flügge, Adametz, Maschek, Zimmermann, Migula and Tils, *loc. cit.*	Everywhere
Pediococcus albus (Lindn.)	..	Lindner in 'Bot. Centralbl.,' 1888, p. 99	
Coccus A of Fontin	..	Roux, *loc. cit.*, p. 284	
Cocco stellato of Maschek	..	Roux, *loc. cit.*, p. 288	
Coccus ruber	..	Roux, *loc. cit.*, p. 288	This appears to be the *M. carneus* of Zimmermann (Roux)
Bacillus aerophilus (Lib.)	..	Roux, *loc. cit.*, p. 296	Common in air
B. acidi lactici (Zopf)	*Bacterium acidi lactici* (Zopf)	Tils, *loc. cit.*	Rare in water, common in milk
Bacillus Adametzi (Trev.)	"*Brauner pigment-bildender Wasser-bacillus*" (Adametz et Wichm.)	Adam. and Wichm., in 'Mitth. Oester. Vers.-Stat. f. Brauerei,' &c., Wien, 1888, p. 51	Cultivated from water
B. albus (Eis.)	"*Weisser-bacillus*" of Eisenberg	Roux, *loc. cit.*, p. 346	
B. albus putidus (Masch.)	..	Roux, *loc. cit.*, p. 309	
B. arborescens (Frankl.)	..	Frankland, in 'Zeitschr. f. Hyg.,' vol. 6, 1889, p. 373, and Tils, *loc. cit.*	In Thames, &c.
B. aquatilis (Trev.)	"Bacille de l'eau" of Babes	Frankl., *loc. cit.*, and Cornil and Babes, 'Les Bact.,' p. 167	Common in Kent waters
B. aquatilis sulcatus (Weichs.)	..	Weichselbaum, in 'Das Oesterr. Sanitätswesen,' 1889, Nos. 14—23	The author describes *five* varieties of this "false typhus bacillus"

B. aureus (Adam.)	..	Roux, *loc. cit.*, p. 337; Eisenberg, *loc. cit.*, p. 140	Also found on skin of eczema patients (Eisenberg)
B. aurantiacus (Frankl.)	..	Frankl., *loc. cit.*	Kent water
B. aurantius (Trev.)	"*Orange-rother Wasser-bacillus*" of Adametz	Adam. & Wichm., in 'Oester. Vers.-Stat. f. Brauerei,' &c., 1888, p. 50	In water and air
B. berolinensis indicus (Claess.)	..	Claessen, in 'Centr. f. Bakt., 1890, p. 13	
B. brunneus (Adam.)	..	Roux, *loc. cit.*, p. 339	
B. butyricus (Hueppe)	..	Roux, *loc. cit.*, p. 310	
B. cloacæ (Jord.)	..	Jordan, in 'Exp. Invest. by the State Board of Massachusetts, 1890'	Common in St. Lawrence
B. circularis (Jord.)	..	Jordan, *loc. cit.*	
B. cœruleus (All. Smith)	..	Allen Smith, in 'Med. News,' 1887, p. 758	Schuylkill river
B. constrictus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. cuticularis (Tils)	..	Tils, *loc. cit.*	New species isolated from Freiburg water
B. delicatulatus (Jord.)	..	Jordan, *loc. cit.*	
B. dendriticus (Uffred.)	..	Roux, *loc. cit*	
B. devorans (Zimm.)	..	Zimmermann, *loc. cit.*	
B. erythrosporus (Eidam)	..	Migula, *loc. cit.*	Usually in contaminated water. Absent from running streams
B. flavo-coriaceus (Adam.)	..	Adam. and Wichm., *loc. cit.*	Only in water
B. fluorescens (Trev.)	*B. Pagliani* (Trev.), "*Fluoreszirender Bacillus*" of Eisenberg	Saccardo, 'Syll. Fung.,' vol. 8, p. 980	Water, soil, and even milk
B. fluorescens aureus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. fluorescens liquefaciens (Fl.)	*B. fluorescens* (Trev.), *B. viridi-luteus* (Trev.), "*Grüngelber Bacillus*" of Eisenberg	Migula and Tils, *loc. cit.*; also Podrowsky, *loc. cit.*	A putrefaction form, but occurs in water, and even ice and snow
B. fluorescens longus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. fluorescens non-liquefaciens (Eis.)	*B. aquatilis fluorescens* (Lust.)	Roux, *loc. cit.*, p. 341	

Schizomycetes found in Drinking Water—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
B. fluorescens putidus (Fl.).....	*Bacillus putidus* (Trev.), *B. Trimethylamine* (Bey.)	Migula and Tils, *loc. cit.*	Not in clear running streams
B. fluorescens tenuis (Zimm.) ..	..	Zimmermann, *loc. cit.*	
B. filiformis (Tils)	..	Tils, *loc. cit.*	In Freiburg waters
B. fulvus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. fuscus (Fl.)...............	*B. brunneus* (Schröt.), *Bacterium brunneum* (Schröt.)	Migula, *loc. cit.*	Hitherto on cooked vegetables, &c. We have failed to discover whether this is the one described by Zimmermann (*loc. cit.*)
B. gazoformans (Eis.)	"*Gasbildender Bacillus*" of Eisenberg	Eisenberg, *loc. cit.*, p. 107	
B. geton (Trev.)	"Bacille de l'eau" (*b*) (Babes)	Cornil and Babes, 'Les Bact.,' p. 167	In water only
B. glaucus (Masch.)...........	..	Roux, *loc. cit.*, p. 300	
B. gracilis (Zimm.)	..	Zimmermann, *loc. cit.*	
B. guttatus (Zimm.)...........	..	Zimmermann, *loc. cit.*	
B. helvolus (Zimm.)...........	..	Zimmermann, *loc. cit.*	
B. hyalinus (Jord.)	..	Jordan, *loc. cit.*	
B. hydrocharis (Trev.).........	"Bacille de l'eau" (*c*) (Babes)	Cornil and Babes, *loc. cit.*	Common in water
B. implexus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. latericius (Adam.)	"*Ziegel-rother Wasser-bacillus*" (Adam.), *B. erythræus* (Trev.)	G. Roux, *loc. cit.*, p. 343; Adam. and Wichm., *loc. cit.*	In water only
B. janthinus (Fl.).............	*Bacillus violaceus* (Schröt.), *Bacterium janthinum* (Zopf), *Chromobacterium violaceum* (Bergowz.)	Tils, *loc. cit.*, and Frankl., *loc. cit.*, and Podrowsky, *loc. cit.*	A common putrefactive form in dirty waters, &c.
B. lactis viscosus (Adam.)......	..	Adametz, in 'Berliner Landwirthsch. Jahrb.,' 1891	In water of Vienna

B. lividus (Pl. and Pr.)	..	Plagge and Proskauer, 'Zeitschr. f. Hyg.,' vol. **2**, p. 463, and Roux, *loc. cit.*, p. 303	
B. Lineola (Trev.)	*Bacterium Lineola* (Muell.), *Vibrio Lineola* (Muell.), *Bacterium nitrosum* (Maggi)	Aradas, in 'Atti dell' Accad. in Catania,' 1888, p. 1	Common in stagnant water
B. liodermos (Fl.)	..	Tils, *loc. cit.*	Hitherto on potatoes
B. liquefaciens (Eis.)	..	Eisenberg, *loc cit.*	
B. luteus (Fl.)	..	Migula and Tils, *loc. cit.*	Very common in putrefactions
B. liquidus (Frankl.)	..	Frankland, *loc. cit.*	In Thames
B. megaterium (De By.)	..	Tils, *loc. cit.*	Hitherto in vegetable infusions only
B. membranaceus amethystinus (Eis.)	..	Eisenberg, *loc. cit.*, p. 421	
B. mesentericus fuscus (Fl.)	*B. mesentericus* (Trev.)	Tils and Migula, *loc. cit.*	Atmospheric dust. Not found in running streams
B. mesentericus ruber (Globig)	..	Roux, *loc. cit.*, p. 321.	On potatoes also
B. mesentericus vulgatus (Fl.)	*B. vulgatus* (Trev.)	Migula and Tils, *loc. cit.*	On potatoes. Not in clear running streams
B. multipediculus (Fl.)	..	Migula, *loc. cit.*	On potatoes also
B. muscoides (Libor.)	*Cornilia muscoides* (Libor.)	Tils, *loc. cit.*; Roux, *loc. cit.*	Known in cheese
B. mycoides (Fl.)	"*Erdebacillus*" (Fl.), "*Wurzelbacillus*" (Eisenb.), *B. radificans* (Pod.)	Tils, *loc. cit.*, and Podrowsky	Common in earth, air, &c. (N.B. Podrowsky)
B. nubilus (Frankl.)	..	Frankland, *loc. cit.*, and Tils, *loc. cit.*	London water
B. ochraceus (Zimm.)	..	Fazio, 'I Microbi delle Acque Minerali,' 1888, and G. Roux, *loc. cit.*, p. 103. Zimmermann, *loc. cit.*	
B. liquefaciens (Doy.)	..	Podrowsky, *loc. cit.*	In urine, if Podrowsky refers to this form. Eisenberg, *loc. cit.*, p. 112, also has a species of this name
B. plicatus (Zimm.)	..	Zimmermann, *loc. cit.*	

Schizomycetes found in Drinking Water—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
B. punctatus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. prodigiosus (Cohn)	..	Migula, *loc. cit.;* Tils, *loc. cit.*	Not in clear running or mountain streams. Common
B. putrificus coli (Fl.)	*B. albuminis* (Schröt.), *B. diaphthirus* (Trev.)	Tils, *loc. cit.*	Hitherto in human excrement
B. pyocyaneus (Gessard)	*B. æruginosus* (Trev.), *Micrococcus pyocyaneus* (Gess.)	Tils, *loc. cit.*	Hitherto in pus
B. pyocyaneus (β)	..	Tils, *loc. cit.*	In Freiburg waters
B. radiatus aquatilis (Zimm.)	..	Zimmermann, *loc. cit.*	
B. ramosus (Eis.)	" *Wurzel-bacillus* " of Eisenberg	Roux, *loc. cit.;* Eisenberg, *loc. cit.*, p. 126	? Same as Flügge's *B. ramosus liquefaciens*
B. reticularis (Jord.)	..	Jordan, *loc. cit.*	
B. ramosus liquefaciens (Fl.)	*B. Praussnitzii* (Trev.)	Migula, *loc. cit.* (Frankland, *loc. cit. ?*)	An aërial form
B. ruber (Frank)	..	Migula, *loc. cit.*	Frank found it in cooked rice
B. rubescens (Jord.)	..	Jordan, *loc. cit.*	
B. rubidus (Eis.)	..	Roux, *loc. cit.;* Eisenberg, 'Bakt. Diag.,' 1891, p. 88	
B. rubifaciens (Zimm.)	..	Zimmermann, *loc. cit.*	
B. saprogenes II (Rosenb.)	*B. telmatis* (Trev.)	Tils, *loc. cit.*	Hitherto on feet
B. subflavus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. superficialis (Jord.)	..	Jordan, *loc. cit.*	
B. subtilis (Ehrenb.)	*Vibrio bacillus* (Müller), *V. subtilis* (Ehrenb.), *Metallacter Bacillus* (Perty)	Tils, *loc. cit.;* Migula, *loc. cit.;* Podrowsky, in 'Centr. für Bakt.,' vol. 10, p. 566	Ubiquitous and common in water. This is the well-known "*Hay-bacillus*"
B. stolonatus (Adam.)	..	Adam. & Wichm., *loc. cit.*	In water containing sugar
B. syncyanus (Ehr.)	*Vitris syncyanus* (Ehr.), *V. cyanogenus* (Fuchs), *Bacterium syncyanum* (Schröt.)	Jordan, *loc. cit.*, and E. Roux, *loc. cit.*, p. 979	Hitherto known in milk

B. tremulus (Koch)	*Cornilia tremula* (Trev.)	Migula, *loc. cit.*	Not in clear running streams
B. tremelloides (Tils)	..	Tils, *loc. cit.*	In Freiburg waters
B. ubiquitus (Jord.)	..	Jordan, *loc. cit.*	
B. ureæ (Miqu.)	*Bacterium ureæ* (Leube), *Urobacillus Pasteurii* (Miqu.)	Migula, *loc. cit.*, and Tils, *loc. cit.*	Not in clear running streams. Usual in urine
B. vermicularis (Tils)	..	Tils, *loc. cit.* (? Frankl., *loc. cit.*)	In water of River Lea
B. vermiculosus (Zimm.)	..	Zimmermann, *loc. cit.*	
B. violaceus (Frankl.)	Not Schröter's form?	Roux, *loc. cit.*	See Roux and Saccardo (*loc. cit.*, p. 979, for synonymy, which is complex, for Eisenberg also gives a form, *loc. cit.*, p. 91, with this name)
B. violaceus-Laurentius (Jord.)	..	Jordan, *loc. cit.*	
B. viscosus (Frankl.)	..	Frankl., *loc. cit.*	In Kent waters
B. viridi-pallescens (Frick.)	*B. viridi-luteus* (Pagl.), "*Grüngelber nicht verflüssigender bacillus*" (Eisenb.)	Tils, *loc. cit.*	In Freiburg waters, common soil
B. Wichmanni (Trev.)	"Gold-gelber Wasser-bacillus" (Adam.)	Adam. & Wichm., *loc. cit.*	An aërial form also
B. Zopfii (Kinth.)	..	Macé, *loc. cit.*	
Bacterium graveolens (Uffred.)	..	Tils, *loc. cit.*	An epidermal form
B. cæruleo-viride (Trev.)	"*Blau-grün-fluorescirendes Bacterium*" (Adametz)	Adam. & Wichm., *loc. cit.*	
B. luteum (List.)	..	Tils, *loc. cit.*; Saccardo, vol. 8, p. 1087	
B. rosaceum (Trev.)	*B. rosaceum metalloides* (Dowdes.), *Bacillus miniaceus* (Zimm.)	Dowdeswell, in 'Ann. de Micrographie,' 1889, p. 310, and Zimmermann, *loc. cit.*	G. Roux suggests the identity of these two forms (*loc. cit.*, p. 305)
B. Termo (Muell.)	*Monas Termo* (Muell.), *Palmella infusiorium* (Ehr.), *Zooglœa Termo* (Cohn), *Bacillus Termo* (Trev.)	Aradas, *loc. cit.*	A very confused form. Macé believes that among the half dozen or so confounded under this name, there is one (*Bacillus Termo*) which may be autonomous (see E. Roux, *loc. cit.*, p. 332)
B. Zürnianum (List.)	*Bacillus Zürnianum* (List.)	Roux, *loc. cit.*, p. 360	

Schizomycetes found in Drinking Water—*continued*.

Species.	Synonyms.	Authority for habitat.	Remarks.
Proteus mirabilis (Hauser)	*Bacillus mirabilis* (Hansen)	Podrowsky, *loc. cit.*, and Tils, *loc. cit.*	A soil and putrefactive form
P. sulphureus (Lind.)	*Bacillus sulphureus* (Holsch.), *Bacterium sulphureum* (Holsch.), *Bacillus sulphohydrogenus* (Miquel)	Podrowsky, *loc. cit.*; Eisenberg, *loc. cit.*, p. 89	In waters contaminated by fæces (synonymy doubtful. Eisenberg, pp. 89 and 129, gives Holschewnikoff's *Bacterium sulphureum* as a separate species)
P. vulgaris (Haus.)	*Bacillus Proteus* (Trev.)	Tils, *loc. cit.*	Soil and infusions
P. Zenkeri (Haus.)	*Bacillus Zenkeri* (Haus.)	Podrowsky, *loc. cit.*, and Tils, *loc. cit.*	Infusions
Spirillum concentricum (Kitas)	..	See Saccardo, vol. 8, pp. 1007 and 1010; Lustig, *loc. cit.*	Confused form?
Sp. rubrum (Esm.)	..	Saccardo, *loc. cit.*, p. 1008; Esmarch, in 'Centr. f. Bakt.,' 1887, p. 225	

Schizomycetes isolated from Ice, Hail, Snow, &c.

Species.	Synonyms.	Authority for habitat.	Remarks.
Bacillus viridi-luteus (Trev.) ...	" *Grüngelber Bacillus*" of Eisenberg, *B. fluorescens liquefaciens* (Fl.)	Schmelck, 'Centr. f. Bakt.,' vol. 4, p. 544, and Bujwid, *loc. cit.*	A very common form
B. fluorescens nivalis (Schm.)...	See p. 65	Schmelck, quoted by G. Roux, *loc. cit.*, p. 300	It is not clear that this is not the same as the above
B. fluorescens putidus (Fl.)	See p. 66	Bujwid, in 'Centr. f. Bakt.,' vol. 1, 1887, p. 592	
B. janthinus (Zopf.)...........	See p. 66	Bujwid, *loc. cit.*	Bujwid also obtained nine other forms in hail

Pathogenic Schizomycetes which have been detected in Potable Waters.

Species.	Synonyms.	Authority for habitat.	Remarks.
Micrococcus Biskra (Heydenr.).	..	Eisenberg, *loc. cit.*, p. 227.	Pathogenic to man and other animals
Bacillus anthracis (Cohn)......	*Pollendera anthracis* (Trev.)	Poincaré in 'Comptes Rend.,' 1880, vol. 91, p. 179.	Must be frequently washed into rivers, &c.
B. canalis capsulatus (R. Mori)	..	Rintaro Mori, *loc. cit.*	
B. canalis parvus (R. Mori)....	..	Rintaro Mori, *loc. cit.*	
B. coli communis (Esch.).......	*Baterium coli commune* (Esch.), *Bacillus Escherichii* (Trev.)	G. Roux, *loc. cit.*, p. 384	It is subject of dispute as to the relations of this "false typhus bacillus" to the true one of Eberth

Pathogenic Schizomycetes which have been detected in Potable Waters—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
B. cuniculicida (Flügge)	*Pasteurella cuniculicida* (Flügge), *Bacillus der Kaninchenseptikæmie* (Koch)	Koch ('Mitth. a. d. K. Gesundh. Amte,' vol. 1, p. 94), Rintaro Mori, *loc. cit.*	Eisenberg (*loc. cit.*, p. 276) points out that this form is probably identical with Pasteur's *B. choleræ gallinarum*
B. dysentericus (Trev.)..........	*Bacillus der Dysenterie* (Klebs) ...	Aradas, *loc. cit.*	
B. hydrophilus fuscus (Sanar.)..	..	Sanarelli, in 'Centr. f. Bakt.,' vol. 9, p. 193	Probably identical with *B. ranicida* of Ernst
B. murisepticus (Flügge)	*B. insidiosus* (Trev.), *B. murinus* (Schröt.), *Bacillus der Mäuseseptikæmie* (Koch)	Rintaro Mori, *loc. cit.*	
Bacillus of meningitis spinalis..	..	Roux, in 'Ann. Inst. Pasteur.'	
B. pyocyaneus (Gess.)..........	..	Tils, *loc. cit.*	Pathogenic ?
B. saprogenes II (Rosenb.).....	..	Tils, *loc. cit.*	Pathogenic ?
B. tetani (Flügge)	*Tetanus-bacillus* (Nicol.), *Pacinia Nicolaievi* (Trev.)	Miquel, *loc. cit.*, p. 109	Its usual habitat is soil
B. typhosus (Eberth)..........	*Vibrio typhosus* (Trev.)	Miquel, 'Manuel Pratique,' p. 115	N.B.—The earlier statements as to occurrence of this form must be received cautiously, as several forms are known to simulate it in growth, shape, size, &c.
Spirillum choleræ asiaticæ (Koch)	..	Koch, *loc. cit.*, Nicati & Kietsch, *loc. cit.*	
Staphylococcus pyogenes aureus (Rosenb.)	..	Tils, *loc. cit.*, Miquel, *loc. cit.*, p. 117; Eisenberg, *loc. cit.*, p. 221	Pathogenic to various animals

Schizomycetes found in Slow Rivers, Canals, Stagnant and Marsh Waters, &c.

Species.	Synonyms.	Authority for habitat.	Remarks.
Cladothrix dichotoma (Cohn) . . .	*Cochlyothrix leptomitoides* (Corda)	Billet, 'Contrib. à l'Étude des Bact.,' Paris, 1890	Ubiquitous, though commonest in stagnant water
Crenothrix Kühniana (Rabenh.)	*Leptothrix Kühniana* (Rabenh.), *Crenothrix polyspora* (Cohn), *Hypheothrix Kühniana* (Rabenh.)	Cohn, in 'Beitr. Biol. Pflanzen,' vol. 3, Heft 1, and Giard, 'Compt. Rend.,' vol. 95, 1882, p. 247	Occurs in flowing rivers, but more characteristic of stagnant water
Sphærotilus natans (Kütz.).	*Leptothrix natans* (Den.)	Eidam, in 'Schles. Gesell. f. Vaterl. Cultur,' 1876	Rivers contaminated by manufactures
Beggiatoa alba (Vauch.).	*Oscillaria alba* (Vauch.), *O. dulcis* (Kütz.), *O. Raineriana* (Kütz.), *Beggiatoa dulcis* (Menegh.), *B. Raineriana* (Menegh.), *B. punctata* (Trevis), *Hygrocrocis Vandelli* (Menegh.)	Cohn, 'Hedwigia,' 1865, p. 81; Zopf, 'Sitzber. der Berlin. Akad.,' 1881; Winogradsky	Common in mud and stagnant waters, and also in thermal and sulphur springs
Bacillus aquatilis sulcatus (Weichselbaum)			
B. De Baryanus (Klein)	..	Klein, in 'Ber. d. Deut. Bot. Ges,' 1889, p. 65	Water in which algæ were putrefying
B. erythrosporus (Eidam)	..	See Table	
B. Fitzianus (Zopf).	*B. subtilis* and *B. æthilicus* (Fitz.)	Zopf, 'Spaltpilze,' Aufl. 3, p. 161	In grass infusions
B. fusisporus (Schröt.).	..	Saccardo, 'Syll. Fung.,' vol. 8, p. 973	In rivers contaminated with sugar-refuse, &c.
B. limosus.	..	Klein, 'Ber. d. Deut. Bot. Ges.,' 1889, p. 65	In foul waters of Freiburg
B. Maydis (Majoc.)	*Bacterium Maydis* (Majoc.)	Saccardo, 'Syll. Fung.,' vol. 8, p. 976	In waters where maize, &c., is putrefying
B. macrosporus (Klein)	..	Klein, *loc. cit.*	In Freiburg waters

Schizomycetes found in Slow Rivers, Canals, Stagnant and Marsh Waters, &c.—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
B. malariæ (Klebs)	..	Klebs & Tommasi-Crudeli, in 'Arch. f. exp. Path.,' 1879	In malarial waters
B. Peroniella (Klein)..........	..	Klein, *loc. cit.*	In water where algæ are rotting
B. sanguineus (Schröt.)........	..	Saccardo, 'Syll. Fung.,' vol. 8, p. 977.	Stagnant waters
B. Sohnsii (Klein)	..	Klein, *loc. cit.*	Stagnant waters
B. sulphureus (Holsch.)........	*Bacterium sulphureum* (Holsch.), *Bacillus sulphydragenus* (Miqu.)	Saccardo, *loc. cit.*, p. 978 (and N.B. Table)	In cloacal waters
B. Sphinx (Trev.).............	*Cornilia Sphinx* (Trev.), "Bacillus mit mehreren seitlichen Sporen" (Koch)	Cohn, in 'Beitr. Biol. Pflanz.,' vol. 2, p. 423	Stagnant waters
B. subtilis (Ehrenb.)...........	..	..	All over
B. stolonatus (Adam.)..........	..	Adam. & Wichm., *loc. cit.*	In waters contaminated with sugar-refuse, &c.
B. thermophilus (Miqu.)........	..	See Table	In waters contaminated with fæces
B. tremulus (Koch)	*Cornilia tremula* (Koch)	Saccardo, *loc. cit.*, p, 1002	Putrefying infusions
B. Hanseni (Rassm.)	*Cornilia Hanseni* (Rassm.)	Saccardo, *loc. cit.*, p. 1001	In water contaminated with malt, &c.
B. ulna (Cohn)	..		
B. virens (Van Tiegh.).........	..	Van Tieghem, in 'Bull. Soc. Bot. France,' 1880, p. 175	Among aquatic plants
B. janthinus.................	..		

Schizomycetes found in Slow Rivers, Canals, Stagnant, and Marsh Waters, &c.—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
Spirillum amyliferum (V. Tiegh)	..	G. Roux, *loc. cit.*, p. 360	With *Leuconostoc*
Sp. concentricum (Kit.)	..	'Mitth. Öst. Vers.-Stat. Brau.' Wien, 1888, p. 63	
Sp. jenense (Ehrenb.)	*Ophidomonas jenensis* (Ehrenb.)	Saccardo, *loc. cit.*, p. 1012	Stagnant waters
Sp. Kochii (Trev.)	*Spirochæte Kochii* (Trev.), "*Spirochaete des Wollsteiners Sees*" (Koch)	Cohn, 'Beiträge,' vol. 2, p. 420	In the Wollstein lake
Sp. leucomelanum (Perty)	*Sp. volutans* var. (Rabenh.)	Saccardo, *loc. cit.*, p. 1012	In water with rotting algæ
Sp. musculus (Mühlh.)	..	Mühlhäuser, in Virchow's 'Arch. f. path. Anat.,' &c., vol. 97, p. 96	Doubtful species; in stagnant water
Sp. pisciculus (Mühlh.)	*Sp. nitrosum* (Maggi)	Mühlh., *loc. cit.*	With the last; common
Sp. plicatile (Ehrenb.)	*Spirulina plicatilis* (Cohn), *Spirochæte plicatilis* (Ehrenb.), *Spirillum Portæ* (Mantez.)	Saccardo, *loc. cit.*, p. 1006	Common in stagnant waters
Sp. propellens (Mühlh.)	..	Mühlh., *loc. cit.*	Common in stagnant waters
Sp. rosaceum (Klein)	..	Klein, in 'Qu. Jl. Micr. Science,' 1875, p. 581	In fæcal waters
Sp. rufum (Perty)	..	Saccardo, *loc. cit.*, p. 1011	Stagnant waters
Sp. serpens (Muell.)	*Vibrio serpens* (Muell.)	Winter, in Rabenh., 'Die Pilze,' p. 63	Very common in stagnant waters
Sp. tenue (Erhenb.)	..	Saccardo, *loc. cit.*, p. 1009	Ponds, &c.; common
Sp. undula (Muell.)	*Vibrio undula* (Muell.), *V. prolifera* (Ehrenb.)	Saccardo, *loc. cit.*, p. 1009	Very common in stagnant waters
Sp. volutans (Ehrenb.)	*Vibrio spirillum* (Muell.), *Melanella spirillum* (Bory.)	Saccardo, *loc. cit.*, p. 1012	Common everywhere in stagnating waters
Vibrio aureus (Weib.)	*Spirillum aureum* (Weib.)	Weibel, in 'Centr. f. Bakt.,' 1838, vol. 4, p. 260	In canal mud
V. flavescens (Weib.)	*Spirillum flavescens* (Weib.)	Weibel, *loc. cit.*	In canal mud

Schizomycetes found in Slow Rivers, Canals, Stagnant and Marsh Waters, &c.—*continued.*

Species.	Synonyms.	Authority for habitat.	Remarks.
V. flavus (Weib.)	*Spirillum flavum* (Weib.)	Weibel, *loc. cit.*	In canal mud
V. rugula (Muell.)	*Spirillum rugula* (Winter), *Melanella flexuosa* (Bory.)	Saccardo, *op. cit.*, p. 1005	Stagnant waters
V. saprophiles (Weib.)	*Spirillum saprophilum* (Trev.)	Weibel, *loc. cit.*	In infusions of vegetable matter. (Three varieties)
Spiromonas Cohnii (Warm.)	..	Warming, 'Om nogle Daum. Bakt.,' p. 370	In foul water
Sp. volubilis (Perty)	..	Saccardo, *loc. cit.*, p. 1015	Stagnant water
Bacterium enchelys (Ehrenb.)	*Bacillus enchelys* (Trev.)	Saccardo, *loc. cit.*, p. 1023	In Neva and dirty waters in Russia
B. catenula (Dujard.)	*B. catenula* (Trev.)	Saccardo, *loc. cit.*, p. 1024	Ponds and stagnant waters
B. tremulans (Ehrenb.)	*Vibrio tremulans* (Ehrenb.), *Bacillus tremulans* (Trev.), *B. nitrosus* (Maggi)	Saccardo, *loc. cit.*, p. 1023	Common in ponds and stagnant pools
B. punctum (Muell.)	*Monas punctum* (Muell.), *Melanella monadina* (Bory.), *Bacterium tremulans* (Cohn), *Bacillus punctum* (Trev.)	Saccardo, *loc. cit.*, p. 1023	Common in ponds and stagnant pools
Bacterium cyaneo-fuscus (Bey.)	..	Beyerinck, in 'Bot. Zeitg.,' 1891, No. 43	
B. Lineola (Muell.)	..		
B. merismopedioides (Zopf)	..		
B. Termo (Duj.)	..		
Clostrydium butyricum (Prazm.)	"*Vibrion butyrique*" (Pasteur), *Bacillus amylobacter* (Van Tiegh.), *Bacterium navicula* (Reinke)	Saccardo, *loc. cit.*, p. 1003	In decaying plants and saccharine refuse
Proteus vulgaris (Hans.)	..		

Sarcina hyalina (Winter)	*Lampropedia hyalina* (Ehrenb.), *Merismopedia hyalina* (Kütz.), *Gonium hyalinum* (Ehrenb.), *Pediococcus hyalinus* (Trev.)	Saccardo, *loc. cit.*, p. 1048	Not uncommon in stagnant water
S. Reitenbachii (Winter)	*Pediococcus Reitenbachii* (Trev.), *Merismopedium Reitenbachii* (Caspary)	Saccardo, *loc. cit.*, p. 1048	In vegetable infusions, and, occasionally, in fresh waters
Merismopedia violacea (Kütz.)	*Pediococcus violaceus* (Trev.), *Agmenellum violaceum* (Breb.)	Saccardo, *loc. cit.*, p. 1048	Not uncommon in stagnant water
S. paludosa (Schröt.)	..	Schröt., 'Pilz. Schles.,' p. 153	In waters contaminated with sugar refuse
S. candida (Lindner)	..	Lindner, in 'Bot. Centr.,' 1888, p. 99	In aquarium
Leuconostoc mesenterioides (Cienk.)	*Ascococcus mesenterioides* (Cienk.), *A. Mendesii* (Van Tiegh.)	Cienkowski, in 'Arb. der Naturf. Gesell. Univ. Charkoff,' 1878, vol. 12	In waters of sugar manufactories
Micrococcus crepusculum (Ehrb.)	..		
M. agilis (Ali-Cohn)	..		
Myconostoc gregarium (Cohn)	..	Cohn, in 'Beitr. Biol. Pflanz.,' vol. 1, Heft 3, p. 183	In stagnant waters

Schizomycetes which have been found in Sea Water.

Species.	Synonyms.	Authorities for habitat.	Remarks.
Beggiatoa Cohnii (Trev.)	*B. alba* var. *marina* (Cohn)	Cohn, in 'Hedwigia,' 1865, p. 82	In aquaria
B. mirabilis (Cohn)	..	Cohn, *loc. cit.*	
B. pellucida (Cohn)	..	Cohn, *loc. cit.*	
B. minima (Warm.)	..	Warming, *loc. cit.*	Coast of Denmark
B. Meyeniana (Trev.)	*Oscillatoria* (Meyen)	See Saccardo, p. 938	In Atlantic. Doubtful species
B. lanugo (Ag.)	*Leptomitus lanugo* (Ag.)		French coast. Doubtful species
Phragmidothrix multiseptata (Engl.)	..	Saccardo, p. 935	

Schizomycetes which have been found in Sea Water—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
Agonium centrale (Oerst.)	..	Saccardo, p. 939	
Cladothrix intricata (Russ.)	..	Russell, 'Zeitschr. f. Hyg.,' vol. 11, 1891, p. 165	
Leptothrix mucor (Oerst.)	*Leptotrichia mucor* (Oerst.), *Beggiatoa Oerstedii* (Rab.), *B. mucor* (Trev.)	Rabenhorst, 'Flor. Alg. Europ.,' vol. 2 p. 94	
L. radians (Kütz.)	*Leptotrichia radians* (Kütz.)	Rabenhorst, *loc. cit.*, p. 74	
Leptothrix spissa (Rab.)	*L. spissa* (Rab.)	Rabenhorst, *loc. cit.*, p. 74	
Bacterium Balbiani (Bill.)	*Bacillus Balbiani* (Trev.)	Billet, 'Comptes Rend.,' vol. 107, 1888, p. 423	
B. griseum (Warm.)	*Micrococcus griseus* (Winter), *Bacillus griseus* (Trev.)	Warming., *loc. cit.*	
B. littoreum (Warm.)	*Bacillus littoreus* (Trev.)	Warming, *loc. cit.*	
B. microtis (Trev.)	*Bacillus microtis* (Trev.), *Bacterium microsporum* (Trev.)		
B. fusiformis (Warm.)	*Mantegazzæa fusiformis* (Warm.)		
Kurthia Laminariæ (Billet)	*Bacterium Laminariæ* (Billet), *Billetia Laminariæ* (Trev.)	Billet, 'Comptes Rend.,' vol. 106, 1888, p. 293	
Photobacterium luminosum (Beyer.)	*Vibrio luminosus* (Beyer.), *Bacillus luminosus* (Trev.)	Beyerinck, 'Arch. Néerland.,' vol. 23, 1889, p. 403	Phosphorescent in North Sea
Ph. Fischeri (Beyer.)	*Bacillus Fischeri* (Trev.)	Beyerinck, *loc. cit.*	Phosphorescent in Baltic
Ph. indicum (Fischer)	*Bacillus phosphorescens* (Fischer), *Pasteurella phosphorescens* (Fischer)	Beyerinck, *loc. cit.*	West Indies
Ph. phosphorescens (Cohn)	*Bacterium phosphorescens* (Herm.), *Bacillus Hermesi* (Trev.)	Beyerinck, *loc. cit.*	Common phosphorescent forms of the sea
Ph. Pflügeri (Ludw.)	..	Beyerinck, *loc. cit.*	
Ph. balticum (Beyer.)	..	'Versl. en Med. d. K. Akad. Amsterdam,' 1890, p. 239	Phosphorescent in Baltic

Schizomycetes which have been found in Sea Water—*continued.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
Bacillus cyaneophosphorescens (Kütz.)	..	Kütz., in 'Centr. f. Bakt.,' 1891, vol. 9, p. 158	In sea near Sydney.
B. smaragdinophosphorescens (Kütz.)	..	Ditto	Ditto
B. argenteophosphorescens (Kütz.) (var. I, II, and III, and *liquefaciens*)	..	Ditto	Ditto
Streptococcus phosphoreus (Cohn)	*Micrococcus phosphoreus* (Cohn), *M. lucens* (Van Tiegh.), *M. Pflügeri* (Ludw.), *Bacterium lucens* (Nuesch), *Anthrobacterium Pflügeri* (De By.), *Photobacterium phosphorescens* (Beyer.)	Beyerinck, 1889, *loc. cit.*; Saccardo, 'Syll. Fung.,' vol. 8, 1890, p. 1064	Common on rotting fish
Bacillus granulosus (Russ.)	..	Russell, *loc. cit.*	
B. halophilus (Russ.)	..		
B. limosus (Russ.)	..		
B. litoralis (Russ.)	..		
B. thalassophilus (Russ.).......	..		
Spirillum attenuatum (Warm.)..	..	Warming, *loc. cit.*	
S. giganteum (Warm.)	*Spirochæte giganteum* (Warm.)	Warming, *loc. cit.*	
S. marinum (Russ.)...........	..	Russell, *loc. cit.*	
Spirillum sanguineum (Ehr.) ...	*Ophidomonas sanguinea* (Ehr.), *Thiospirillum sanguineum* (Winogr.)	Cohn, 'Beiträge,' &c., vol. 1, Heft 3, p. 169	A sulphobacterium
S. violaceum (Warm.)	..	Warming, *loc. cit.*	
S. volutans (Ehr.)	*Vibriospirillum* (Müll.), *Melanella spirillum* (Bory.)	Warming, *loc. cit.*	A very common form. It is Warming's var. *robustum* which occurs in sea

Schizomycetes which have been found in Sea Water—*continued*.

Species.	Synonyms.	Authority for habitat.	Remarks.
Monas Mülleri (Warm.)	..	Warming, *loc. cit.*	
Sarcina littoralis (Oerst.)......	*Lampropedia littoralis* (Oerst.), *Pediococcus littoralis* (Trev.) *Erythroconis littoralis* (Oerst.), *Sarcina Morrhuæ* (Farl.), *Coniothecium Bertherandi* (Miqu.)	See Saccardo, *loc. cit.*, p. 1049.	On crabs, &c.

Schizomycetes found in Brackish Waters.

Species.	Synonyms.	Authority for habitat.	Remarks.
Spirillum attenuatum (Warm.) . *S. leucomelaneum* (Perty.) ...... *S. Rosenbergii* (Warm.)........ *S. sanguineum* (Warm.)........ *S. violaceum* (Warm.)..........	..	Warming., *loc. cit.*	

Schizomycetes found in Ferruginous Waters.

Species.	Synonyms.	Authority for habitat.	Remarks.
Crenothrix Kühniana (Rab.) ..	*C. polyspora* (Cohn), *Leptothrix Kühnianx* (Rab.), *Hypeothrix Kühniana* (Rab.)	Winogradsky	
Cladothrix dichotoma			
Leptothrix ochracea (Kütz.)			
Sphærotilus ochraceus (Bréb.)			
Lampropedia ochracea (Trev.)			

Mineral Waters.

Species.	Synonyms.	Authority for habitat.	Remarks.
Bacillus ochraceus	..	Fazio, 'I Microbi delle Acque minerali'	
B. liquefaciens			
Micrococcus candicans candidus			
Bacterium chlorinum (Engel.) ..	..	..	Fazio says *Bacil. virens*, V. Tegh.

Schizomycetes found in Sulphurous Waters.

Species.	Synonyms.	Authority for habitat.	Remarks.
Beggiatoa alba (Vauch.)	See p. 255		
B. leptomitiformis (Mengh.)	*Oscillaria leptomitiformis* (Mengh.)	See Saccardo, p. 937	
Clathrocystis roseo-persicina			
Leptotrichia nivea (Rab.)	*Beggiatoa nivea* (Rab.), *Leptonema niveum* (Rab.), *Symphyothrix nivea* (Brügg.), *Thiothrix nivea* (Winogr.)	Winogradsky, 'Beitr.'	
L. tenuis (Winogr.)	*Thiothrix tenuis* (Winogr.)	Winogradsky, *loc. cit.*	
L. tenuissima (Winogr.)	*Thiothrix tenuissima* (Winogr.)		
Thiodictyon elegans (Winogr.)	..		
T. Winogradskyi (Trev.)	..		
Mantegazzæa Winogradskyi (Trev.)	*Rhabdochromatium fusiforme* (Winogr.)		
M. rosea (Cohn)	*Rhabdomonas rosea* (Cohn), *Bacterium roseum* (Trev.), *Rhabdochromatium roseum* (Winogr.)*		* Possibly forms of *Clathrocystis roseo-persicina.* See also Saccardo, p. 943
M. minor (Winogr.)	*Rhabdochromatium minus* (Winogr.)*		
Monas Okenii (Ehr.)	*Bacterium Okenii* (Ehr.), *Chromatium Okenii* (Perty)		
Monas vinosa (Cohn)	*Bacterium vinosum* (Cohn), *Chromatium vinosum* (Winogr.), *Bacillus vinosus* (Trev.)		
Spirillum volutans (Ehr.)	See p. 257	Saccardo, *loc. cit.*, p. 1012	
Bacterium Weissii (Perty)	*Chromatium Weissii* (Perty), *Bacillus Weissii* (Trev.)	Winogradsky, *loc. cit.*	
B. minus (Winogr.)	*Chromatium minus* (Winogr.), *Bacillus minor* (Trev.)		Possibly mere forms of *Monas Okenii*, &c. See Saccardo, p. 1027

B. minutissimum (Winogr.).....	*Chromatium minutissimum* (Winogr.), *Bacillus minutissimus* (Trev.)	Winogradsky, *loc. cit.*	Possibly mere forms of *Monas Okenii*, &c. See Saccardo, p. 1027
Cenomesia albida (Trev.).......	..	See Saccardo, *loc. cit.*, p. 1040	
C. lilacina (Trev.)............			
Thyocystis violacea (Winogr.)...	..	Winogradsky, *loc. cit.*	
T. rufa (Winogr.)............			
Thiothece gelatinosa (Winogr.)..			
Amœbobacter roseus (Winogr.)..			
A. bacillosus (Winogr.)			
A. granulum (Winogr.)			
Thiopolycoccus ruber (Winogr.) .			
Sarcina rosea (Schröt.)........	*Sarcina sulphurata* (Winogr.)	Winogradsky, in 'Bot. Zeit.,' 1887, Nos. 31—37	
Lampropedia rosea (Winogr.) ..	*Pediococcus roseus* (Trev.), *Thiopedia rosea* (Winogr.)	Winogradsky, *loc. cit.*	
Thiocapsa roseo-persicina (Winogr.)			

Schizomycetes found in Thermal Springs.

Species.	Synonyms.	Authorities for habitat.	Remarks.
Sphærotilus thermalis (Kütz.) ..	*Merizomyria aponina* (Kütz.)	See Saccardo, *loc. cit.*, p. 927	
S. lacteus (Kütz.)	..		
Deloniella lutea (Kütz.)	*Hypeothrix lutea* (Kütz.), *Leptothrix lutea* (Rab.), *Leptotrichia lutea* (Trev.)	Saccardo, *loc. cit.*, p. 929	
Beggiatoa arachnoida (Ag.)....	*Oscillarea arachnoidea* (Ag.), *O. versatilis* (Kütz.), *Beggiatoa versatilis* (Trev.)	Saccardo, *loc. cit.*, p. 937	
B. iridescens (Menengh.).......	*Oscillaria iridescens* (Kütz)		
B. alba (Vauch.)..............	See p. 255		
B. leptomitiformis (Menengh.)..	..		
Ascococcus thermophilus (Hansg.)	..	Hansgirg, in 'Oester. Bot. Zeitschr.,' 1888, p. 5	Saccardo says a variety of *Ascococcus Billrothii* (Cohn), *loc. cit.*, p. 1039
Micrococcus thermophilus (Hansg.)	*Micrococcus Neufvillei* (Trev.)		

Unidentified forms in Water.*

Species.	Synonyms.	Authorities for habitat.	Remarks.
Violetter liquefying bacillus	..	Eisenberg, *loc. cit.*	
Weisser streptococcus	..	Tils, *loc. cit.*	
Wurmförmiger streptococcus	..		
Verflüssigender brauner bacillus	..		
Weisser bacillus (Maschek)	..		
Kartoffel-bacillus	..		
Citron-gelber bacillus	..		
Gold-gelber bacillus	..		
Crême-farbiger micrococcus	..		
Fleisch-farbiger bacillus (nov. sp.)	..		
Perlschnur-bacillus	..		
Pigment producirender bacillus	..	Karlinski, in 'Arch. f. Hyg.,' 1889, p. 113	
Gelber grün-fluorescirender bacillus	..		
Weisser bacillus	..		
Gelber verflüssigender bacillus	..		
Weiss-gelblicher bacillus	..		

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* *I.e.*, forms as to the synonymy of which we are doubtful.

Finally we append a tabular statement showing the duration of life note that the experiments quoted have been made under very be compared closely. Nevertheless, it has appeared advisable to in this connexion.

Appendix C.—Behaviour of *Bacillus*

Observers.	Temperature.	Distilled water.	Sterilised ordinary water.	Non-sterilised ordinary water.
Straus and Dubarry. (N.B., proved can form spores in distilled water)	20° C.	131 days (?)	28 days* 65 days†	..
Hochstetter	13—14° to	3 days	3 days‡	..
,, ...	18—20°	Over 154 days (sp.)	Over 154 days‡ (sp.)	..
Hueppe........	16°	..	5 days	..
Gärtner........	12°	..	6 days	..
Meade Bolton ..	20°	Over 3 months (sp.)	Over 3 months (sp.)	..
,, ..	35°	Less than 3 months (sp.)	3 months (sp.)	
,, ..	35°	..	55 hours	
Naegeli........	..	1 year (sp.)		
Koch..........	..	1 year (sp.)		
Kraus	10°·5	..	..	2—4 days
Uffelmann......	12—20°	..	..	3 months (sp.)
Karlinski	8°	..	..	1—3 days
Braem.........	..	8—12 days		
Wolffhügel and Riedel	8—10°	..	..	..
,,	12—16°	..	..	..
,,	30—35°	..	..	..
Frankland, P. F.	15—20°	Over 60 days (sp.)	Over 60 days (sp.)	..

of certain pathogenic forms in various waters. It is necessary to different conditions by the different observers, and that they cannot compile these results, if only to show how much remains to be done

anthracis in Water.

Foul water.	Sea water or Concentrated Salt solution.	Mineral waters.	Remarks.
			Refers to bacilli * Water of Ourcq † Pure water of Vanne
..	..	15 min. to 1 hour§	Refers to bacilli and not to spores
..	..	Over 154 days§	Spores
..	..	..	‡ Berlin tap water § Seltzer water Bacilli only
..	..	..	All = spores
..	..	..	,, ,,
..	..	..	Employed three waters; viz., the Munich town supply, and two well waters
..	..	..	Drinking water
3 days	..	..	Panke water, both filtered and unfiltered
Over 15 days	..	..	It seems impossible to avoid the conclusion that there must have been spores in Wolffhügel's experiments; the bacilli were taken from cultures, not blood
Over 15 days			
Over 60 days (sp.)	..	..	Employed Grand Junction water and London sewage, both sterilised

Behaviour of Typhoid Bacillus

Observers.	Temperature.	Distilled water.	Sterilised ordinary water.	Non-sterilised ordinary water.
Hochstetter	13—20°	5 days	7 days*	..
Meade Bolton ..	20°	2—3 to 30—40, 31 days (sp.)	Over 24 days	
,, ..	35°	10—14—24	Over 14 days	
Heraeus	12°	..	..	Some days
,, ...	37°	..	..	,,
Wolffhügel and Riedel	15—20°	Over 15 days	Over 20 days	
,,	35°	..	..	..
Braem.........	..	188 days		
Kraus	10°·5	..	..	5—7 days,‡ no longer demonstrable on 7th day
Karlinski	8°	..	..	3—6 days
De Mattei and Stagmitta	..	..	4 days	11—14 days
Hueppe........	10—20°	..	20—30 days	..
,, ...	16—20°	..	..	..
Straus and Dubarry	20°	30—35 days	..	32§ to 43‖ days
,,	25°	69 days	..	81 days§
,,	35°	27 days	..	37 days§
Freytag........	..	..	..	..
De Giaxa	..	..	..	..
Uffelmann	..	..	..	Up to 2 weeks
Maschek	18—22°	..	10—80 days	

(*B. typhosus-abdominalis*) in Water.

Foul water.	Sea water or Concentrated Salt solution.	Mineral waters.	Remarks.
..	..	5 to 12 days†	* Berlin tap water † Seltzer water
Over 10 days	..	..	Water of the River Panke
			‡ Three waters used, see above
..	..	..	Innsbruck drinking water
..	..	..	In a well into which the typhoid bacilli had been introduced
5—15 days			
Over 5—30 days			
			§ Water of Ourcq ‖ Water of Vanne (a more pure water)
..	5 months	..	Concentrated salt solution
..	Over 25 days	..	Sea water

Behaviour of *Spirillum*

Observers.	Temperature.	Distilled water.	Sterilised ordinary water.	Non-sterilised ordinary water.
Straus and Dubarry	20°	14 days	26 days* 39 days†	
„	35°	..	30 days*	..
Hochstetter	13—20°	24 hours to 7 days	267—382 to 392 days‡	..
Babes	..	1 day	7 days	..
Wolffhügel and Riedel	16—22°	33 days	2 days to 7 months and even a year	1 to 20 days
Frankland (P. F.)	20°	..	9 days‖	..
Nicati and Rietsch	Ordinary temp. of lab. in winter	20 days	**32—38 days††	..
Ringeling	..	..	..	..
Hueppe	10°	Over 10 days	Up to 30 days	..
„	16—20°	Over 5—10 days		
Kraus	10°·5	1 day	..	1—2 days
Karlinski	8°	3 days	..	2—3 days
De Giaxa	16—18°	..	..	..
Freytag	..	..	..	..
Braem	..	24 hours		
Pfeiffer	..	..	..	7 months
Maschek	..	40 days	60 days	..
Gärtner	11°	..	..	1—2 days

choleræ asiaticæ in Water.

Foul water.	Sea water or Concentrated Salt solution.	Mineral waters.	Remarks.
			* Water of Ourcq † Water of Vanne
..	..	3 hours§	‡ Berlin tap water § Seltzer water
..	..	..	Berlin tap waters
7 months	..	..	Berlin tap waters
Over 11 months¶	..	..	‖ Deep-well (Kent Co.'s water and Thames water) ¶ Sterile sewage (London)
32 days	64 days to 81 days‡‡	..	** Cale †† Canal water ‡‡ Old harbour } All sterile
37 days			
..	..	..	Wiesbaden waters
..	..	..	Three waters employed as above
..	..	..	Drinking waters of Innsbruck
..	2—4 days		
..	6—8 hours		
..	..	..	A little common salt was added to the distilled water

Behaviour of *Bacillus*

Observers.	Temperature.	Distilled water.	Sterilised ordinary water.	Non-sterilised ordinary water.
Straus and Dubarry	38°	Over 115 days	95 days*	
„	35°	25 days	30 days*	
„	20°	24 days	27 days*	

Behaviour of *Staphylococcus*

Straus and Dubarry	20°	4—9 days	19—21 days*	
„	35°	13 days	15 days*	
Meade Bolton ..	20°	20—30 days	20—30 to over 340 days	..
„ ..	35°	Under 5 days	Under 5 days	..
Ferrari	16—18°	Over 5 days to several weeks		
Braem.........	..	25—50 days		

Behaviour of Bacillus of

Straus and Dubarry	20°	19 days	20 days*	

Behaviour of the Bacillus of Swine Plague

Straus and Dubarry	20°	34 days	Over 17 days*	

Behaviour of the Micrococcus of Fowl Cholera

Straus and Dubarry	35°	8 days	30 days*	
„	20°	..	2 days*	

tuberculosis in Water.

Foul water.	Sea water or Concentrated Salt solution.	Mineral waters.	Remarks.
			* Water of Ourcq

pyogenes-aureus in Water.

			* Water of Ourcq
..	..	..	The higher numbers refer to contaminated well water
5—10 days			

Mouse Septicæmia in Water.

			* Water of Ourcq

(*Rothlauf*, *Rouget du Porc*) in Water.

			* Water of Ourcq

(*M. choleræ gallinarum*) in Water.

			* Water of Ourcq

Behaviour of the Bacillus of Rabbit Septicæmia

Observers.	Temperature.	Distilled water.	Sterilised ordinary water.	Non-sterilised ordinary water.
Hochstetter	..	30 minutes to 2 days	..	..

Behaviour of Hochstetter's

Hochstetter	..	14 days	97 days*	..

Behaviour of the Finckler-Prior

Hochstetter	..	4 hours	2 days*	
Frankland, P. F.	..	1 day	1 day*	..

Behaviour of Glanders Bacillus

Straus and Dubarry	..	57 days	..	Over 28* to over 50 days

Behaviour of *Streptococcus*

Straus and Dubarry	20°	8 to 10 days	14* to 15† days	

Behaviour of *Streptococcus*

Frankland, P. F.	20°	Less than 1 hour	5 days*	..

Behaviour of Friedländer's Bacillus

Straus and Dubarry	20°	8 days	4 to 7 days*	

(*Bacillus cuniculicida*) in Water.

	Foul water.	Sea water or Concentrated Salt solution.	Mineral waters.	Remarks.
	..	..	30 minutes to 1 day*	* Seltzer water

" *Bacillus α* " in Water.

	..	..	20 to 60 days †	* Berlin tap water † Seltzer water

Bacillus in Water.

	1 day†			* Berlin tap water * Thames and deep well water † Sterile London sewage

(*B. mallei*) in Water.

				* Water of Vanne † Water of Ourcq

pyogenes in Water.

				* Water of Ourcq † Water of Vanne

erysipelatis (Fehleisen).

	2—5 days†			* Thames water † Sterile London sewage

(*B. pneumoniæ*) in Water.

				* Water of Ourcq

Behaviour of *Micrococcus*

Observers.	Temperature.	Distilled water.	Sterilised ordinary water.	Non-sterilised ordinary water.
Straus and Dubarry	20°	19 days	19 days*	
Hochstetter	10—17°	18 days	18—30 days†	..
Meade Bolton ..	20°	Less than 4 days	Less than 4 days	..
" ..	35°	"	Over 4 days	

Behaviour of *Bacillus pyocyaneus*

Straus and Dubarry	..	More than 13 days	More than 20 days* More than 73 days†	
Frankland, P. F.	20°	More than 53 days		

tetragenus in Water.

Foul water.	Sea water or Concentrated Salt solution.	Mineral waters.	Remarks.
			* Water of Ourcq † Berlin tap water ‡ Seltzer water
..	..	8—11 days‡	
..	..	..	The higher numbers refer to contaminated well water

(Green Pus) in Water.

			* Ourcq † Vanne